# Effects of Recent Climate Change on Terrestrial Vertebrate Ranges in California:

## The Grinnell Resurvey Project

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# Effects of Recent Climate Change on Terrestrial Vertebrate Ranges in California

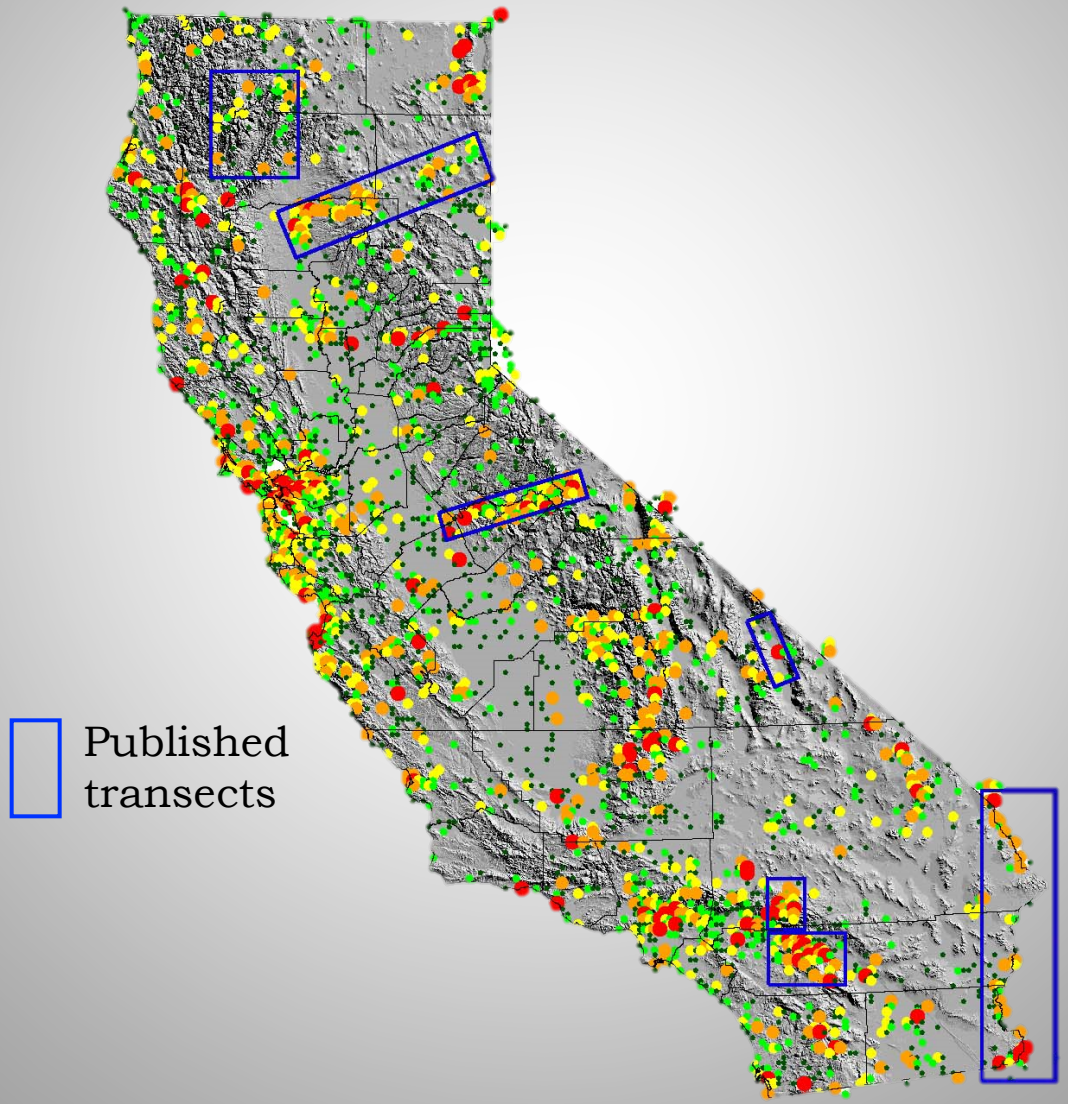
- Vertebrates == Mammals and Birds
- Range == Elevational Range Dynamics
- In California == the Sierra Nevada

# THE GRINNELL RESURVEY PROJECT

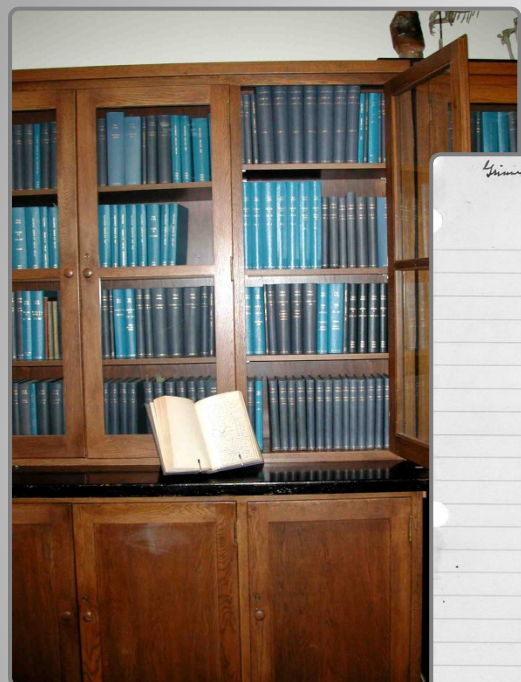
# The Grinnell Legacy

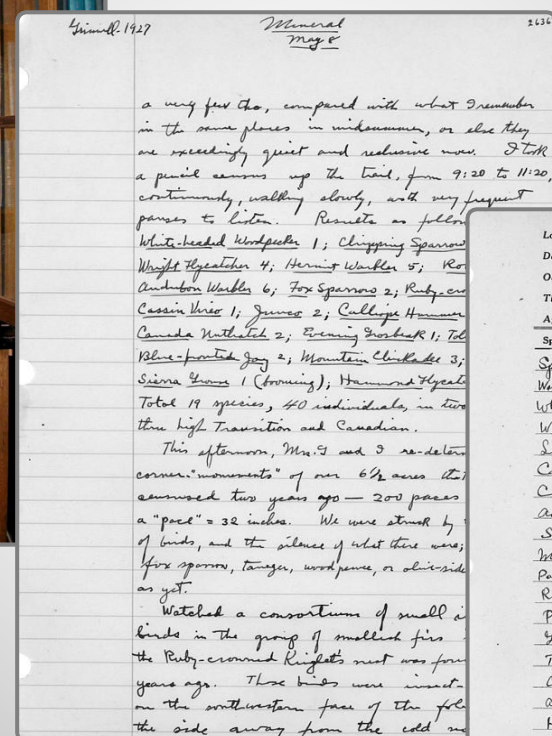
*Joseph Grinnell*
*MVZ Director 1908-39*

# Pre-1940 MVZ: Specimen Locality Records



# Pre-1940 MVZ: Field Notes



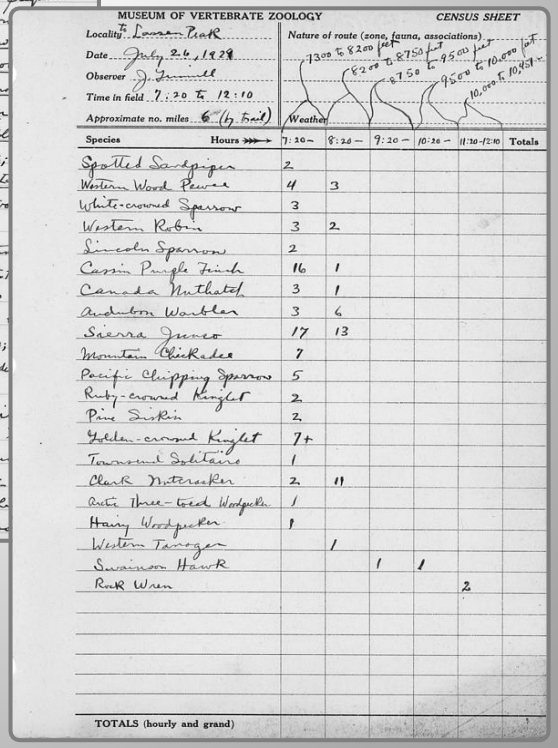


Grinnell-1927 Mineral May 8 2636

a very few tho, compared with what I remember in the same places in midsummer, or else they are exceedingly quiet and reclusive now. I took a pencil census up the trail, from 9:20 to 11:20, continuously, walking slowly, with very frequent pauses to listen. Results as follow
White-headed Woodpecker 1; Clipping Sparrow
Wright Flycatcher 4; Hermit Warbler 5; Ro
Audubon Warbler 6; Fox Sparrow 2; Ruby-cro
Cassin Vireo 1; Junco 2; Calliope Hummer
Canada Nuthatch 2; Evening Grosbeak 1; Tol
Blue-fronted Jay 2; Mountain Chickadee 3;
Sierra Grouse 1 (booming); Hammond Flycat
Total 19 species, 40 individuals, in two
thru high Transition and Canadian.

This afternoon, Mrs. G and I re-deter
corner "monuments" of our 6½ acres that
censused two years ago — 200 paces
a "pace" = 32 inches. We were struck by
of birds, and the silence of what there were;
fox sparrow, tanager, woodpecker, or olive-side
as yet.

Watched a consortium of small i
birds in the group of smallish firs
the Ruby-crowned Kinglet's nest was fou
years ago. These birds were insect-
on the southwestern face of the fol
the side away from the cold n



MUSEUM OF VERTEBRATE ZOOLOGY CENSUS SHEET

Locality: Lassen Peak
Date: July 26, 1928
Observer: J. Grinnell
Time in field: 7:20 to 12:10
Approximate no. miles: 6 (by trail)

Nature of route (zone, fauna, associations): 7300 to 8200 feet; 8200 to 8750 feet; 8750 to 9500 feet; 9500 to 10,000 feet; 10,000 to 10,451 m

Weather

| Species Hours | 7:20 – | 8:20 – | 9:20 – | 10:20 – | 11:20–12:10 | Totals |
|---|---|---|---|---|---|---|
| Spotted Sandpiper | 2 | | | | | |
| Western Wood Pewee | 4 | 3 | | | | |
| White-crowned Sparrow | 3 | | | | | |
| Western Robin | 3 | 2 | | | | |
| Lincoln Sparrow | 2 | | | | | |
| Cassin Purple Finch | 16 | 1 | | | | |
| Canada Nuthatch | 3 | 1 | | | | |
| Audubon Warbler | 3 | 6 | | | | |
| Sierra Junco | 17 | 13 | | | | |
| Mountain Chickadee | 7 | | | | | |
| Pacific Clipping Sparrow | 5 | | | | | |
| Ruby-crowned Kinglet | 2 | | | | | |
| Pine Siskin | 2 | | | | | |
| Golden-crowned Kinglet | 7+ | | | | | |
| Townsend Solitaire | 1 | | | | | |
| Clark Nutcracker | 2 | 11 | | | | |
| Arctic Three-toed Woodpecker | 1 | | | | | |
| Hairy Woodpecker | 1 | | | | | |
| Western Tanager | | 1 | | | | |
| Swainson Hawk | | | 1 | 1 | | |
| Rock Wren | | | | | 2 | |
| TOTALS (hourly and grand) | | | | | | |

# The Grinnell Legacy

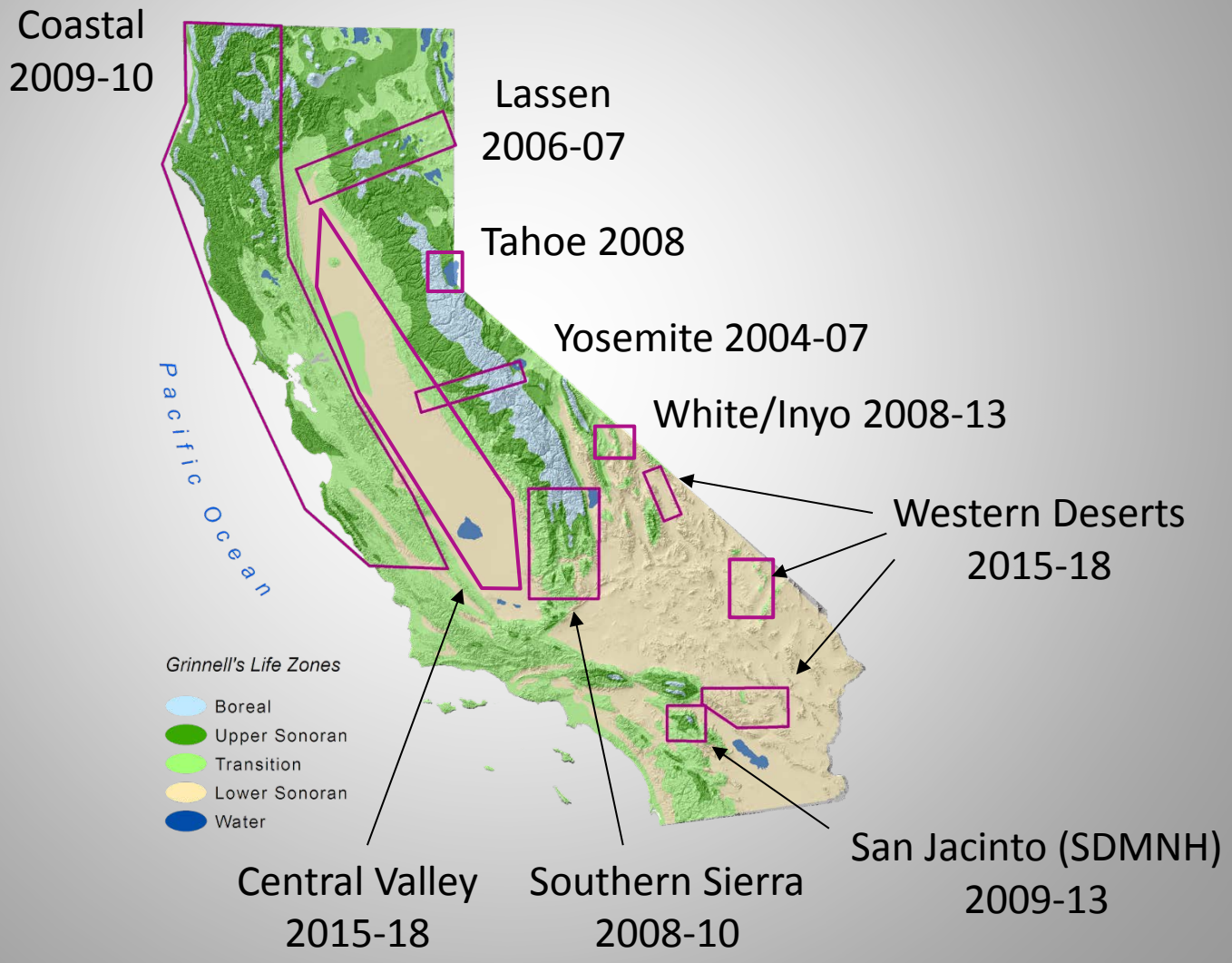
"… the greatest purpose of our museum … will not, however, be realized until the lapse of many years, possibly a century…. And this is that the student of the future will have access to the original record of faunal conditions in California and the west…"

*-Grinnell, 1910*

*Joseph Grinnell*
*MVZ Director 1908-39*

# The Grinnell Resurvey Project

## (*2004 - Present*)



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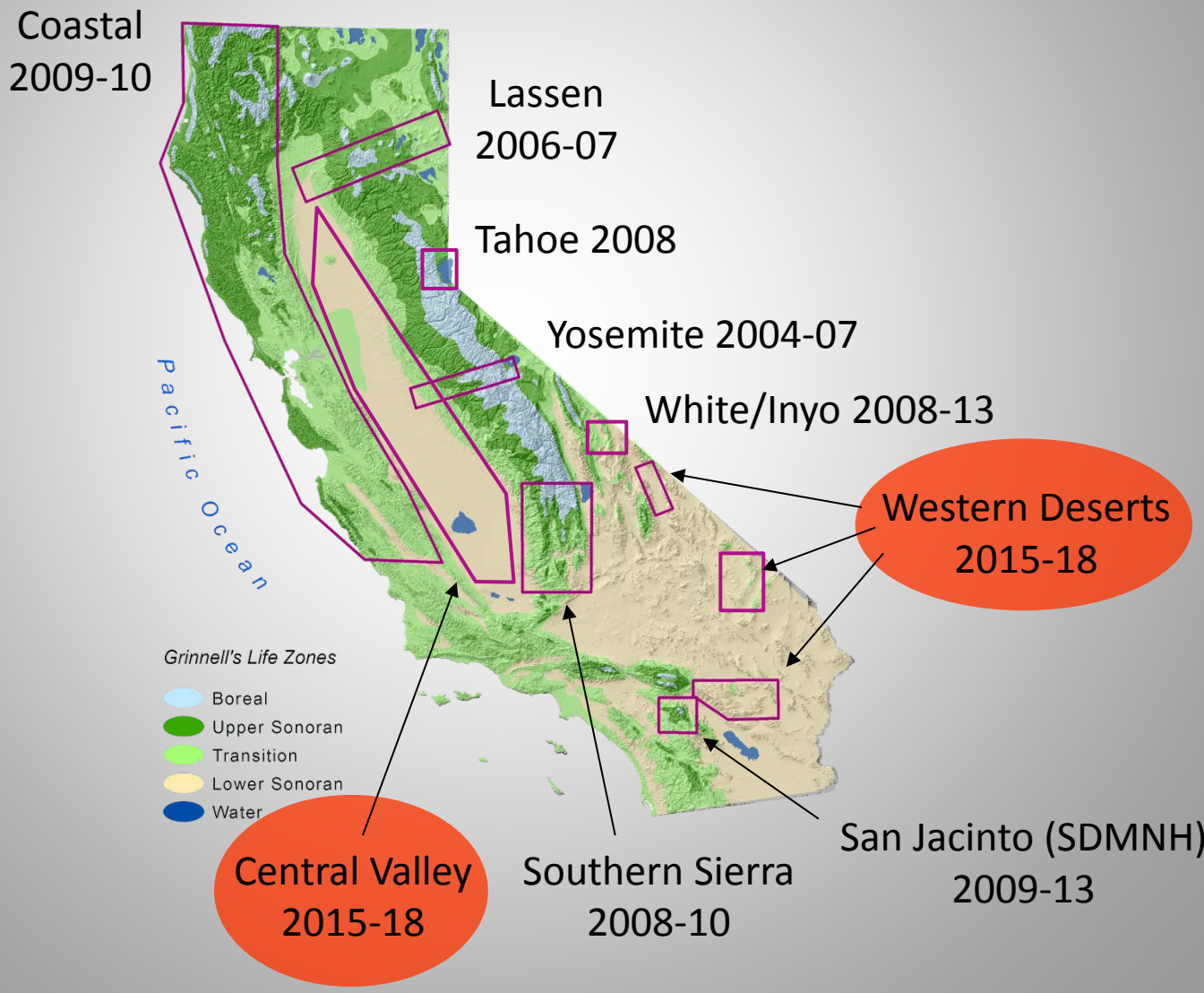
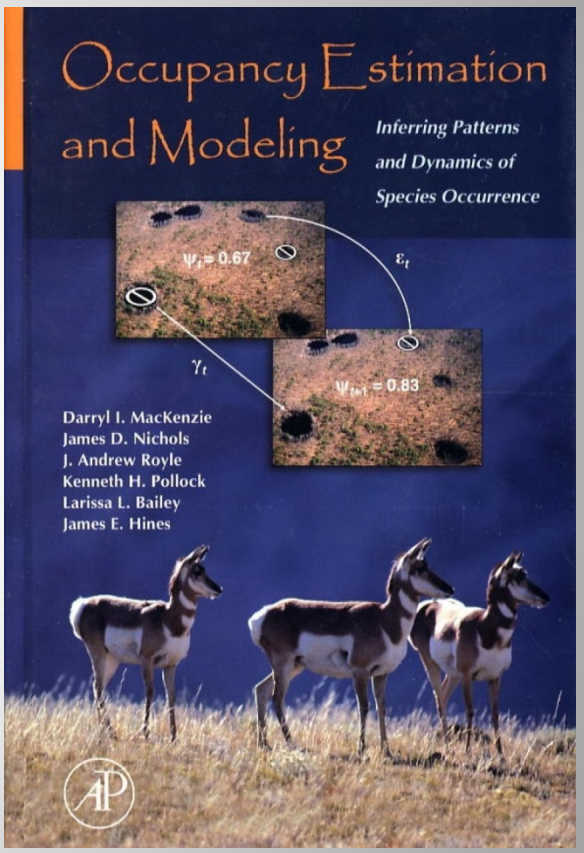


# Linking Historic to Modern: Occupancy Models

- Depend on repeated, within-era temporal surveys
- **Probability of a false absence($P_{fa}$):**
  - Estimates likelihood an observed absence is a true absence and not a lack of detection
  - Across sites (m) based on repeat (n) surveys:

$$P_{fa} = \prod_{j=1}^{m} \prod_{i=1}^{n} \left(1 - p_{ij}\right)$$



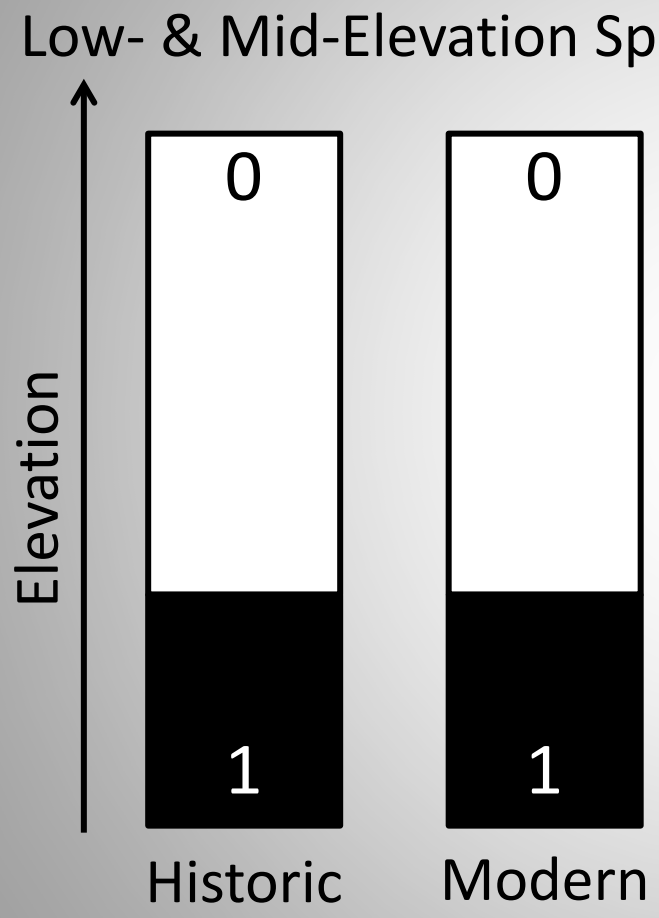

*MacKenzie et al. Ecology 2002, 2004; book in 2006*

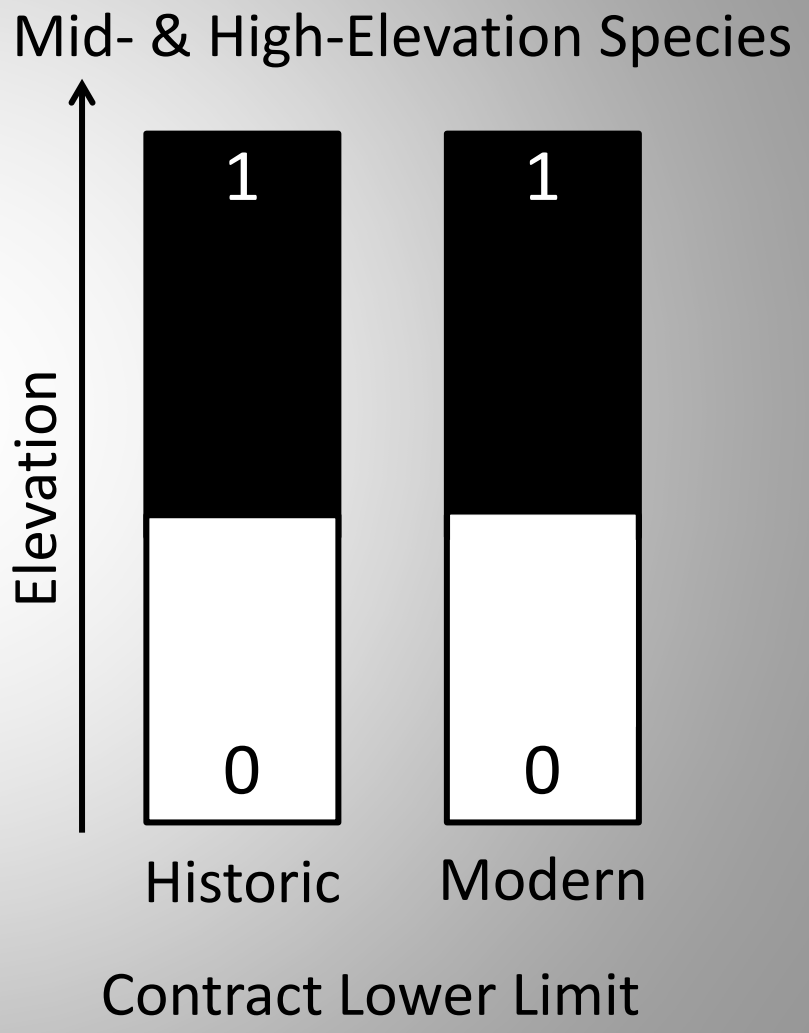
# EFFECTS OF CLIMATE CHANGE ON TERRESTRIAL VERTEBRATE RANGES

# Effects of Climate Change on Terrestrial Vertebrate Ranges

- Elevational Range Dynamics
  - Are naïve predictions of upward shifts sufficient?

# Naïve Range Limit Predictions



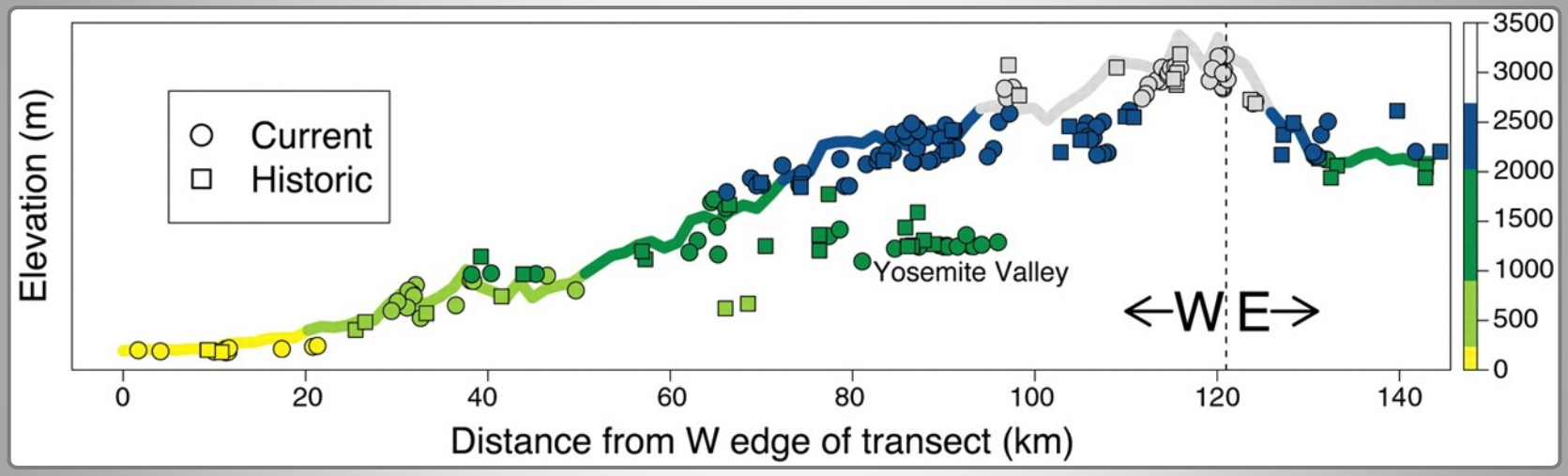



# Globally Coherent Fingerprint: Poleward and Upslope

"Mega" Meta-analyses:

- Parmesan and Yohe 2003. Science:
  - N = 434 species (latitude)
- Chen et al. 2011. Science:
  - N = 764 (latitude)
  - N = 1367 (elevation)

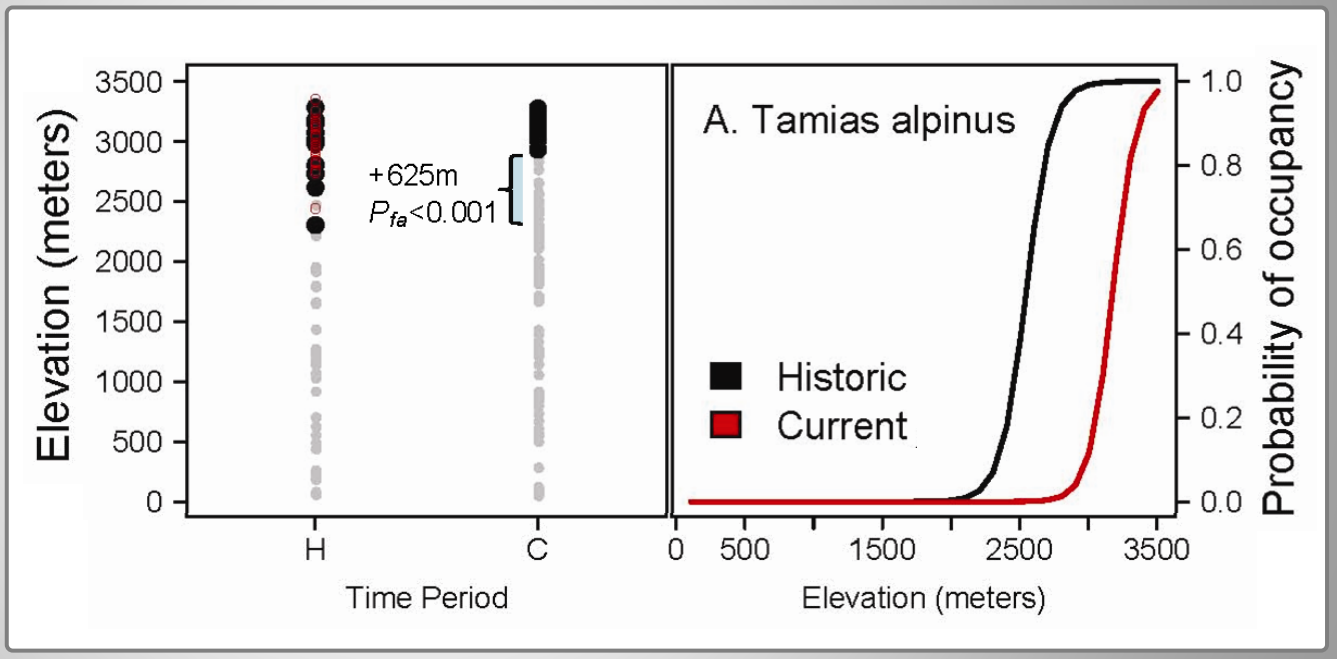
# The Grinnell Resurvey Project: Yosemite Transect, Small Mammals




*Moritz et al. 2008. Science 322: 261-264*

# Mammal Trapping Data and Occupancy Profiles

Alpine chipmunk
*Tamias alpinus*

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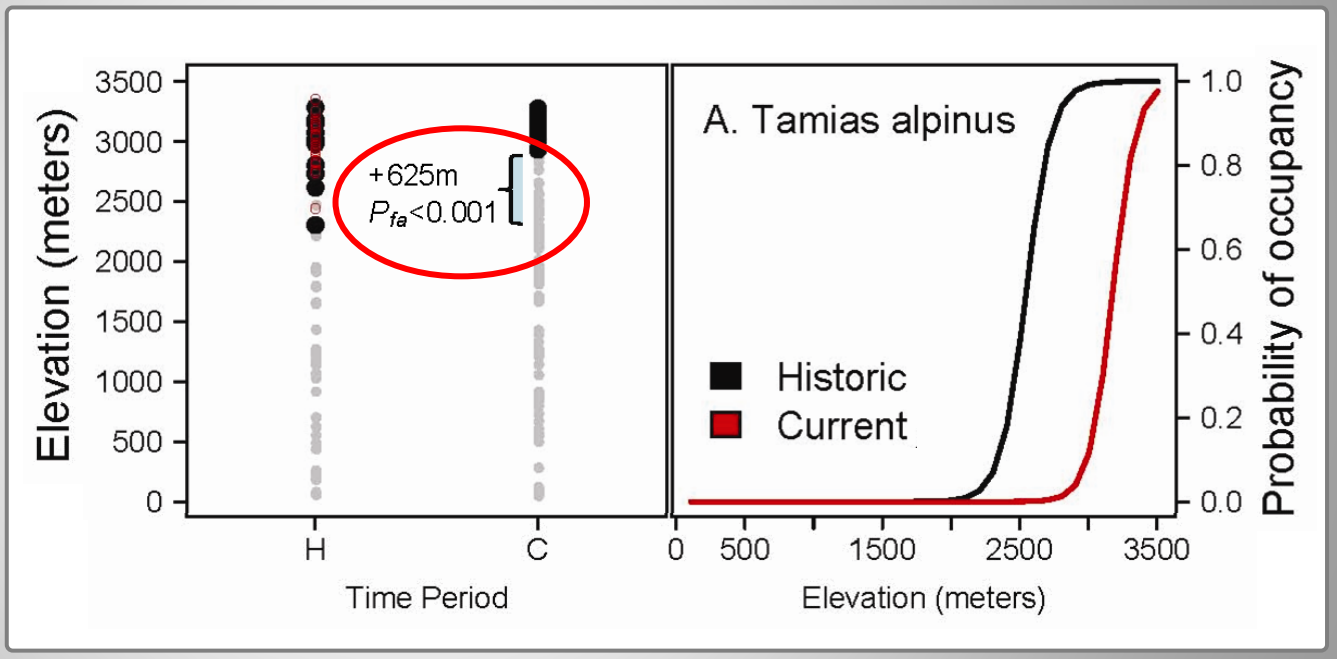


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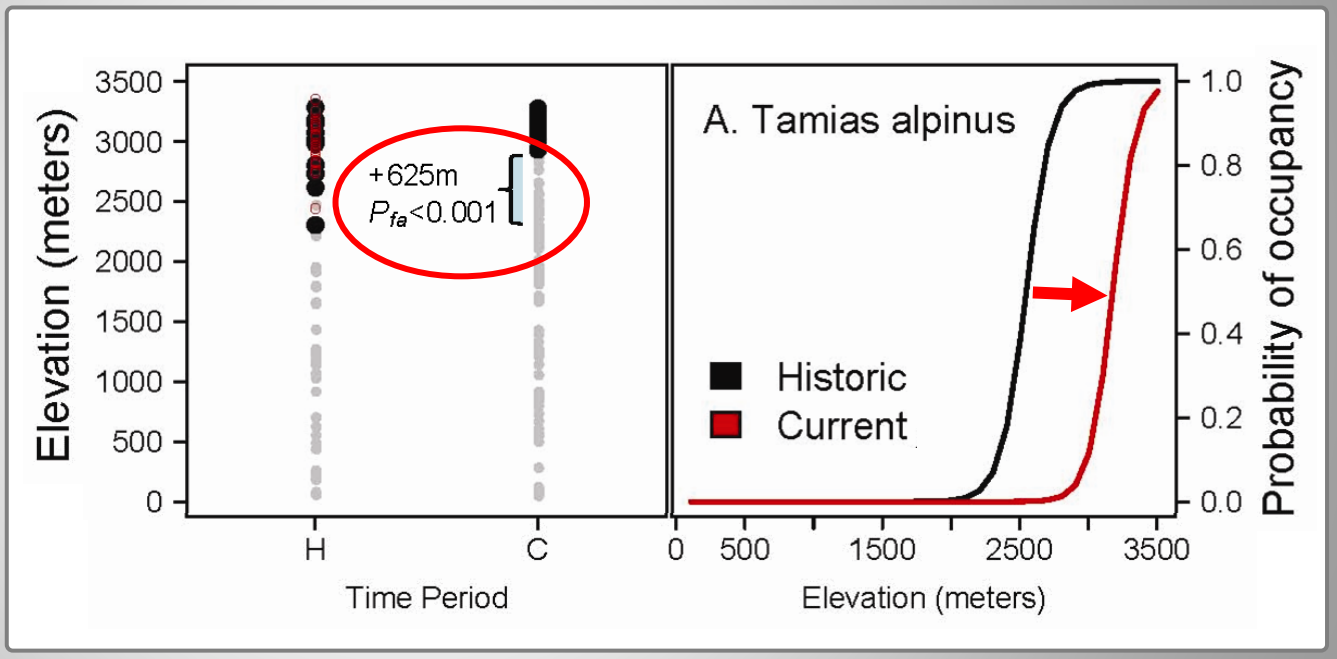


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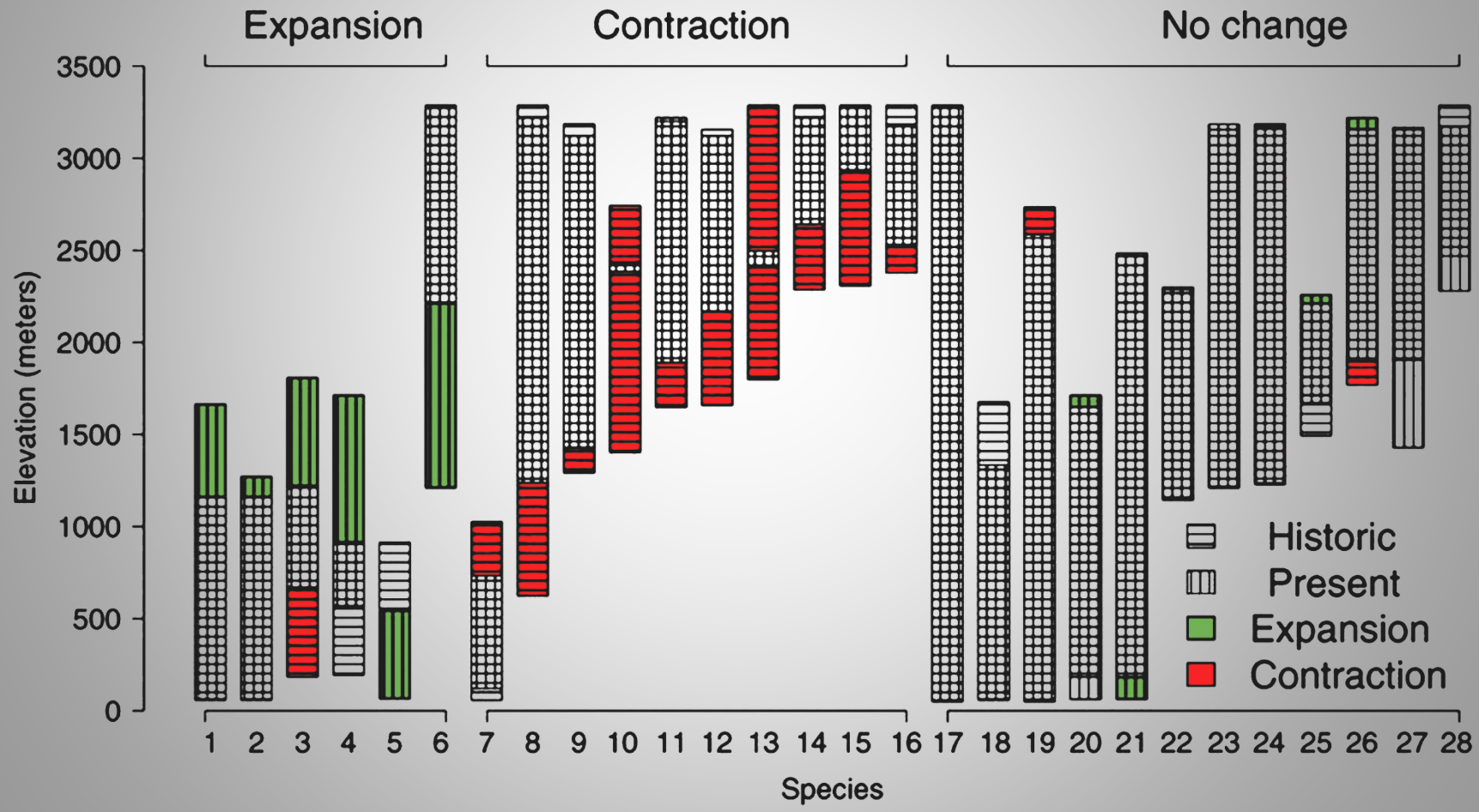
# Elevational Range Change: 28 Yosemite Small Mammal Species

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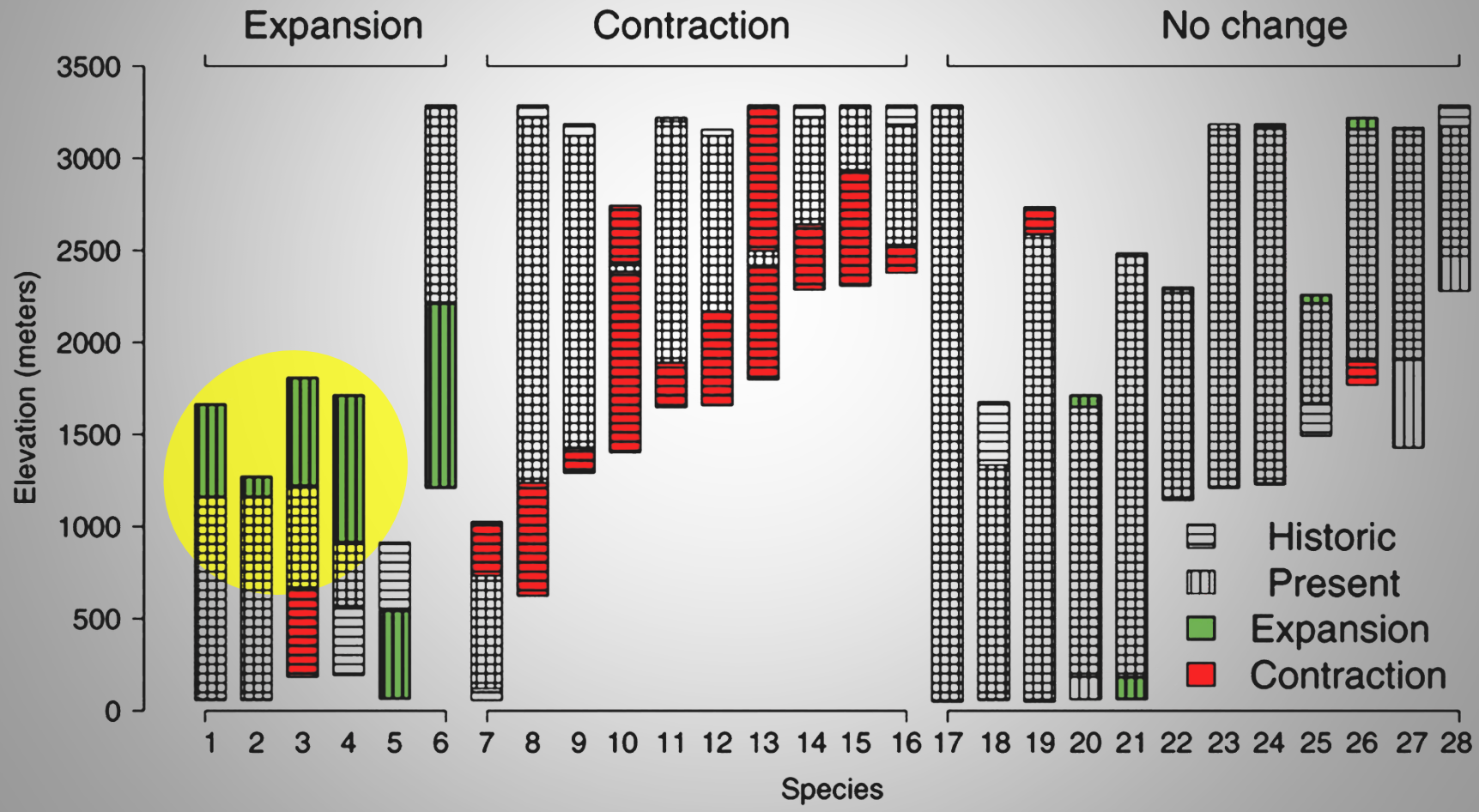
# Elevational Range Change: Range Expansion

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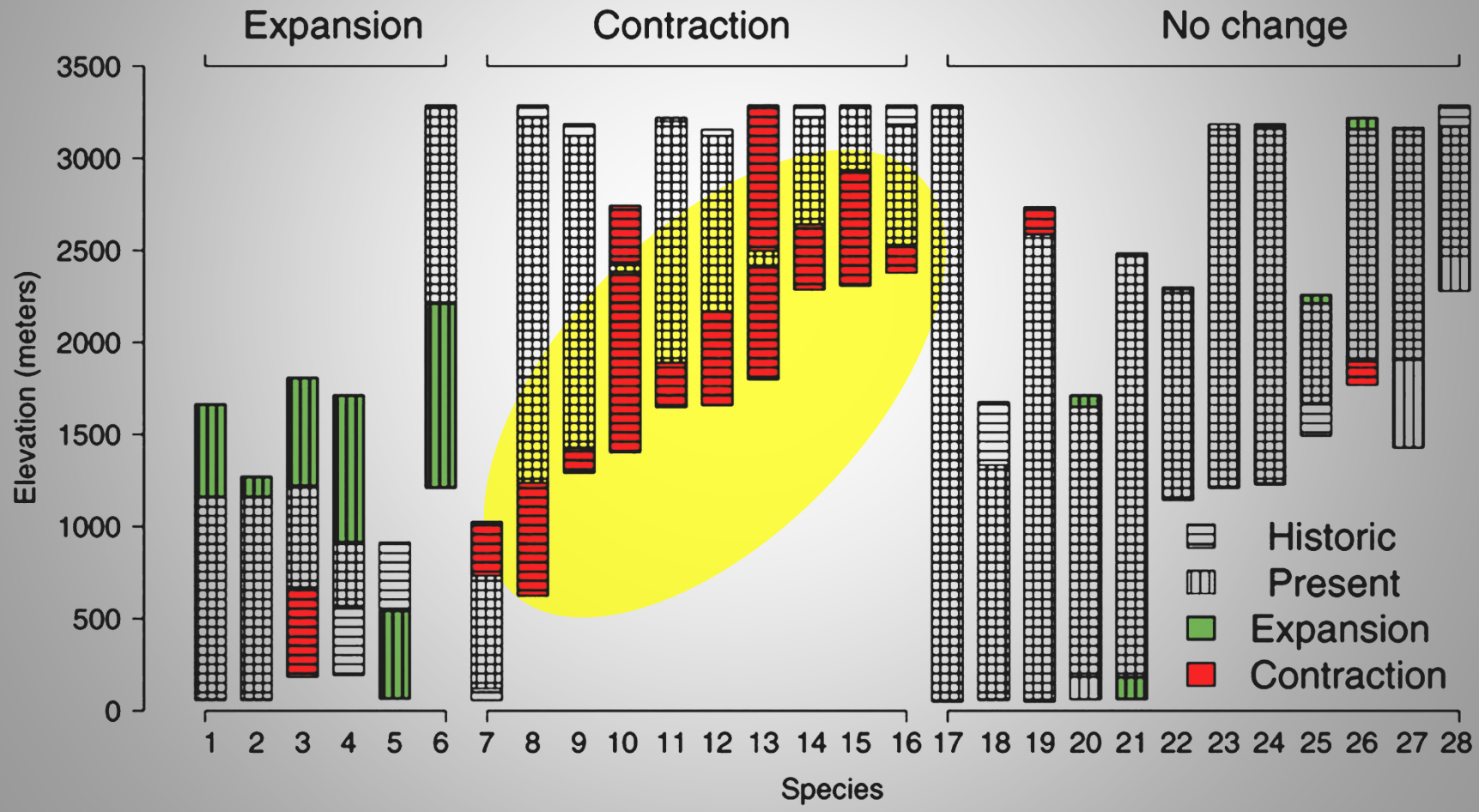
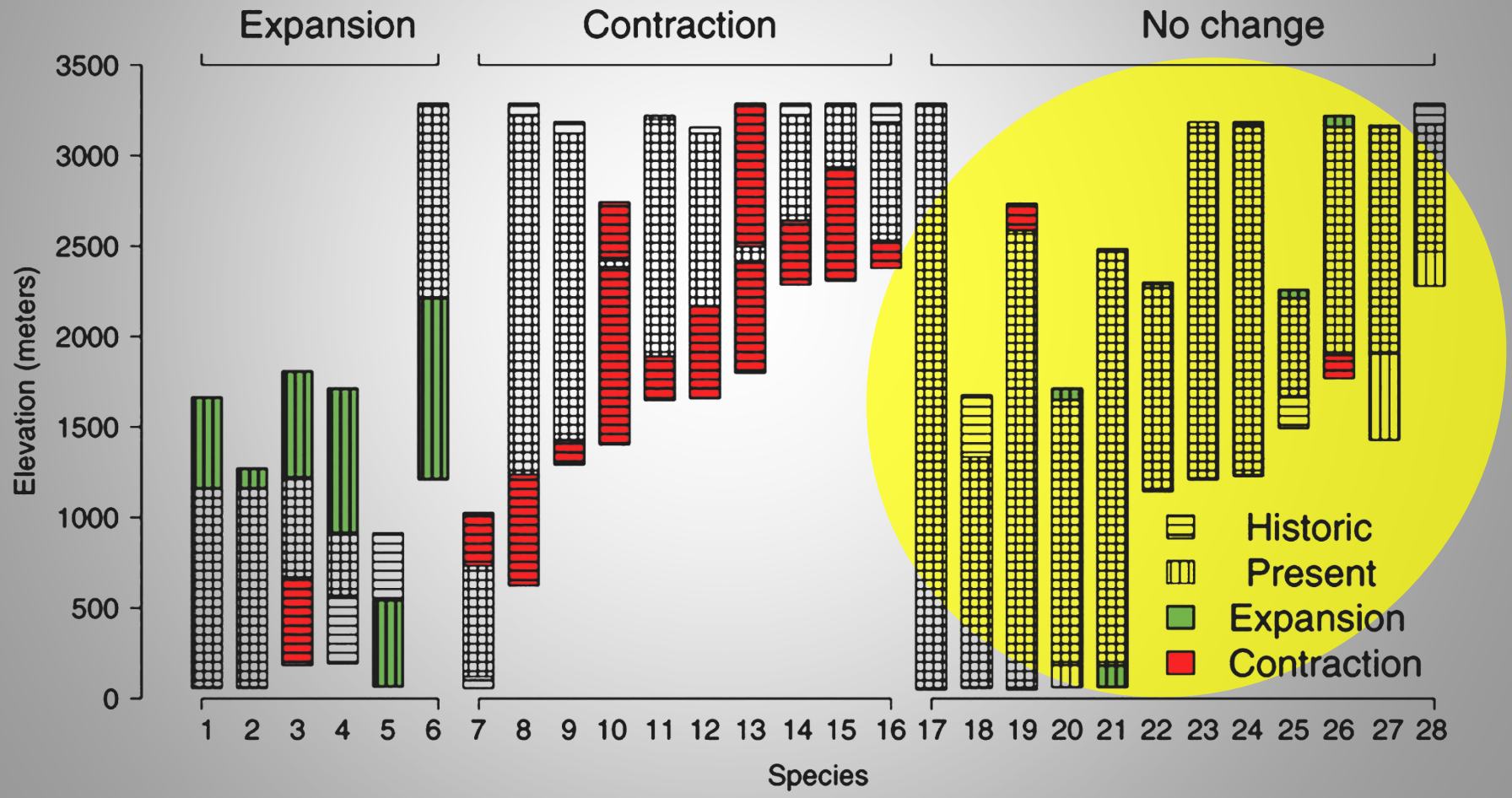
# Elevational Range Change: Range Contraction




*Moritz et al. 2008. Science 322: 261-264*

# Elevational Range Change: No Change

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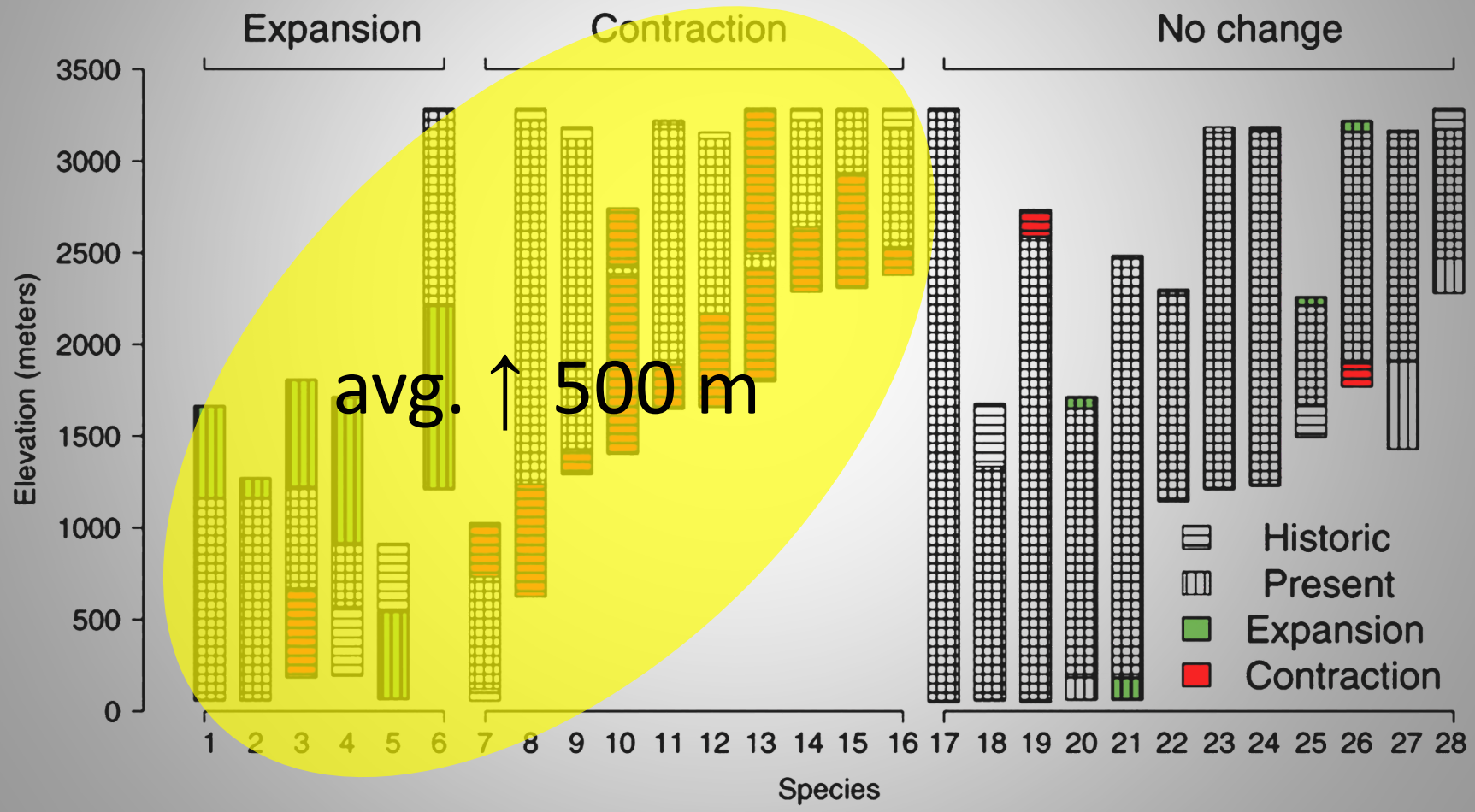
# Elevational Range Change

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# Range Change Predictors

- Strong:
  - Original elevational range:
    - Low: expand upper limit
    - High: contract lower limit

  } Consistent with naïve expectations

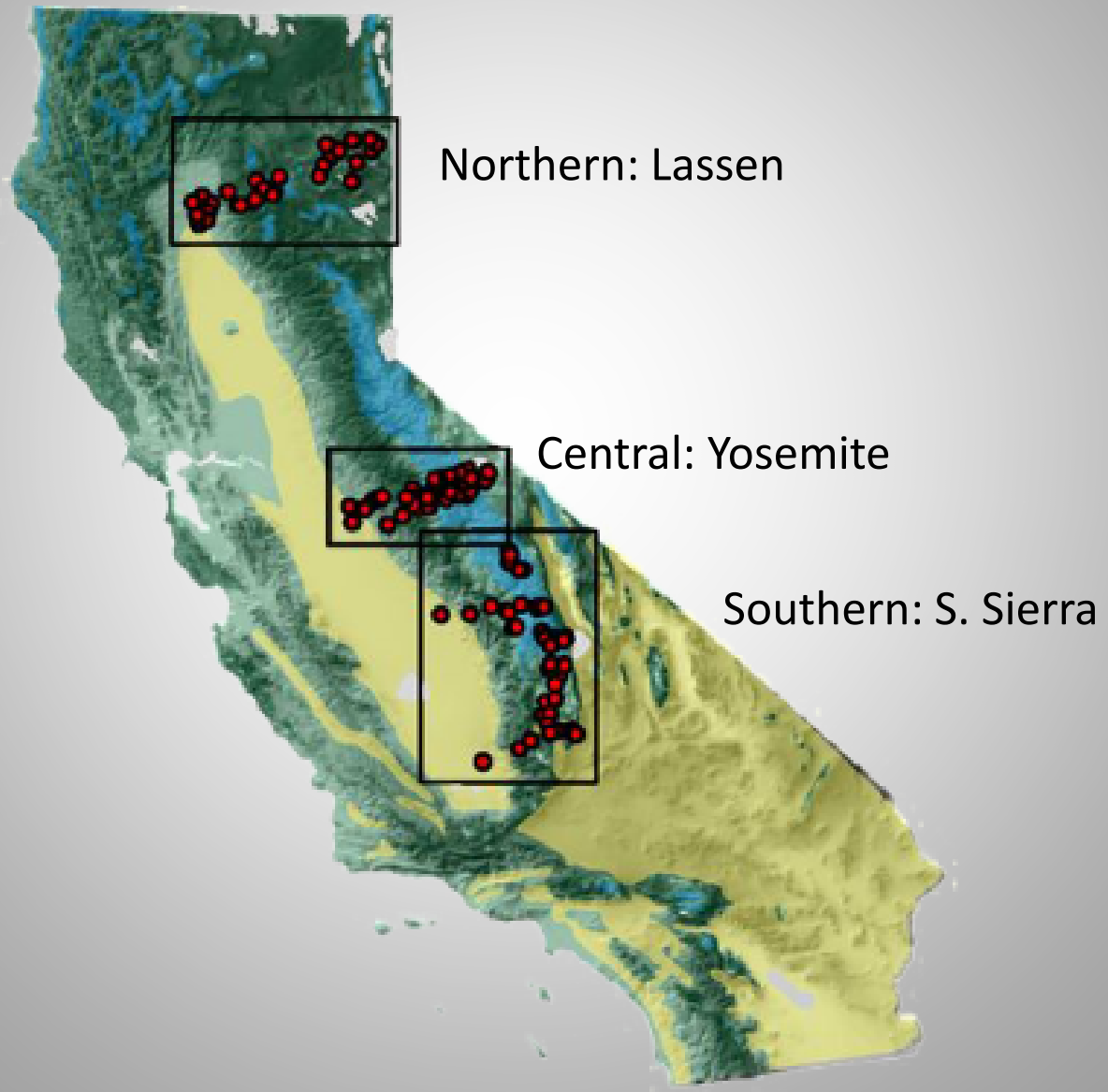
- Weak:
  - Life history and ecological traits, specifically:
    - Longevity (life span in years): longer, ↓ probability of shift
    - Litters per year: more, ↑ probability of shift

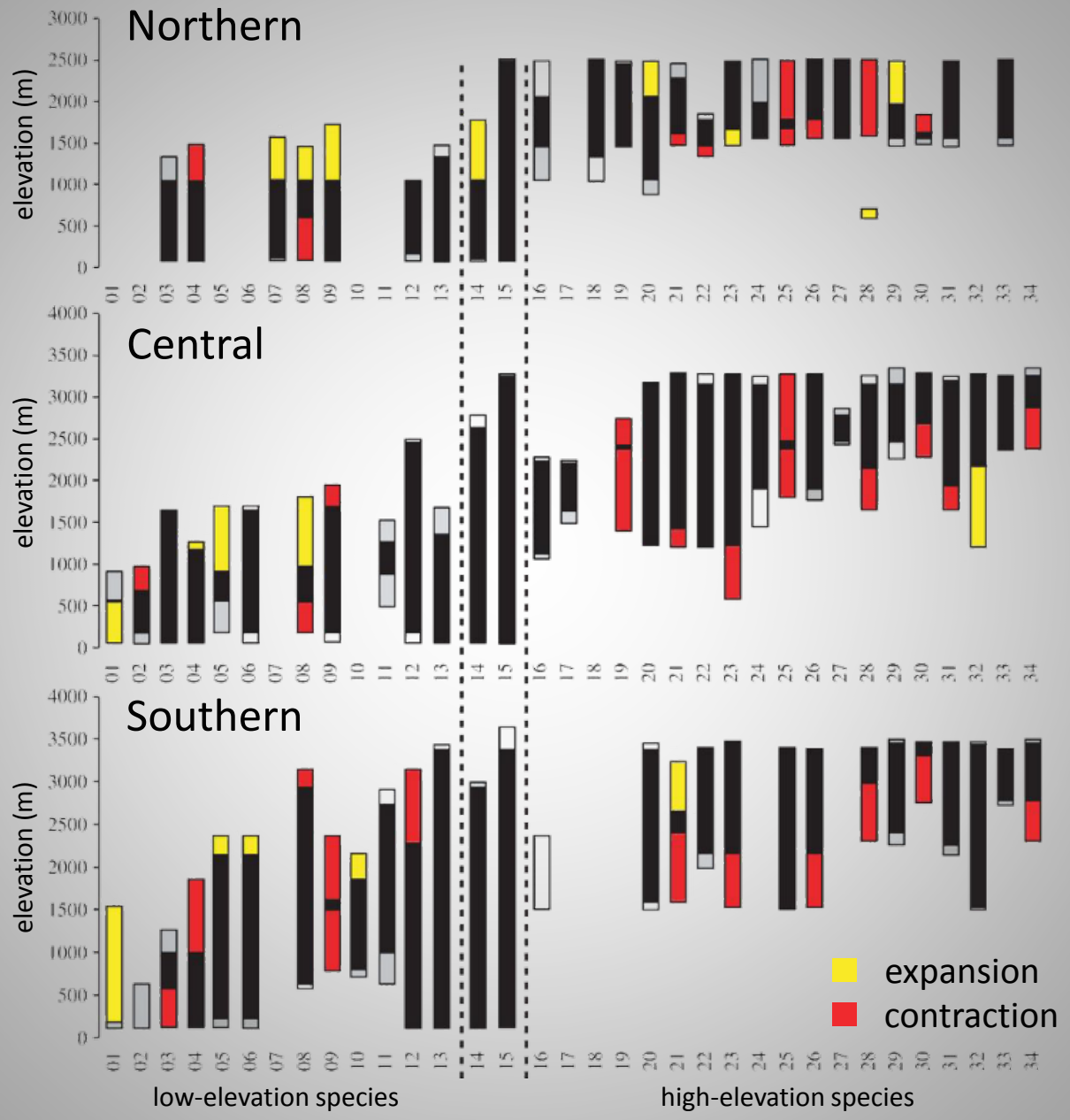
*Moritz et al. 2008. Science 322: 261-264*

# Effects of Climate Change on Terrestrial Vertebrate Ranges

- Elevational Range Dynamics
  - Are naïve predictions of upward shifts sufficient?
  - Dynamics at a broader spatial extent

# Dynamics at a Broader Spatial Extent

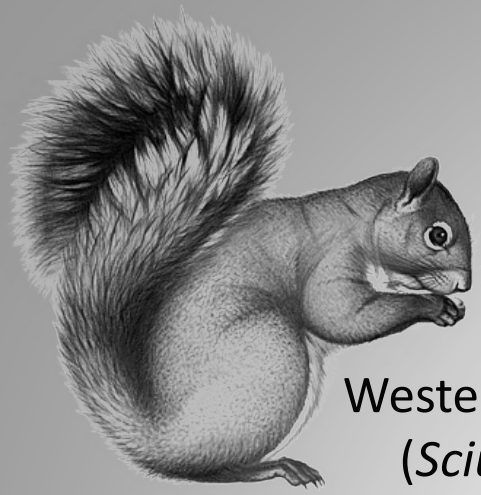




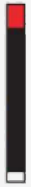

Rowe et al. 2015 Proc Royal Soc B 282: 20141857

Bushy-tailed woodrat
(*Neotoma cinerea*)

*Rowe et al. 2015 Proc Royal Soc B 282: 20141857*

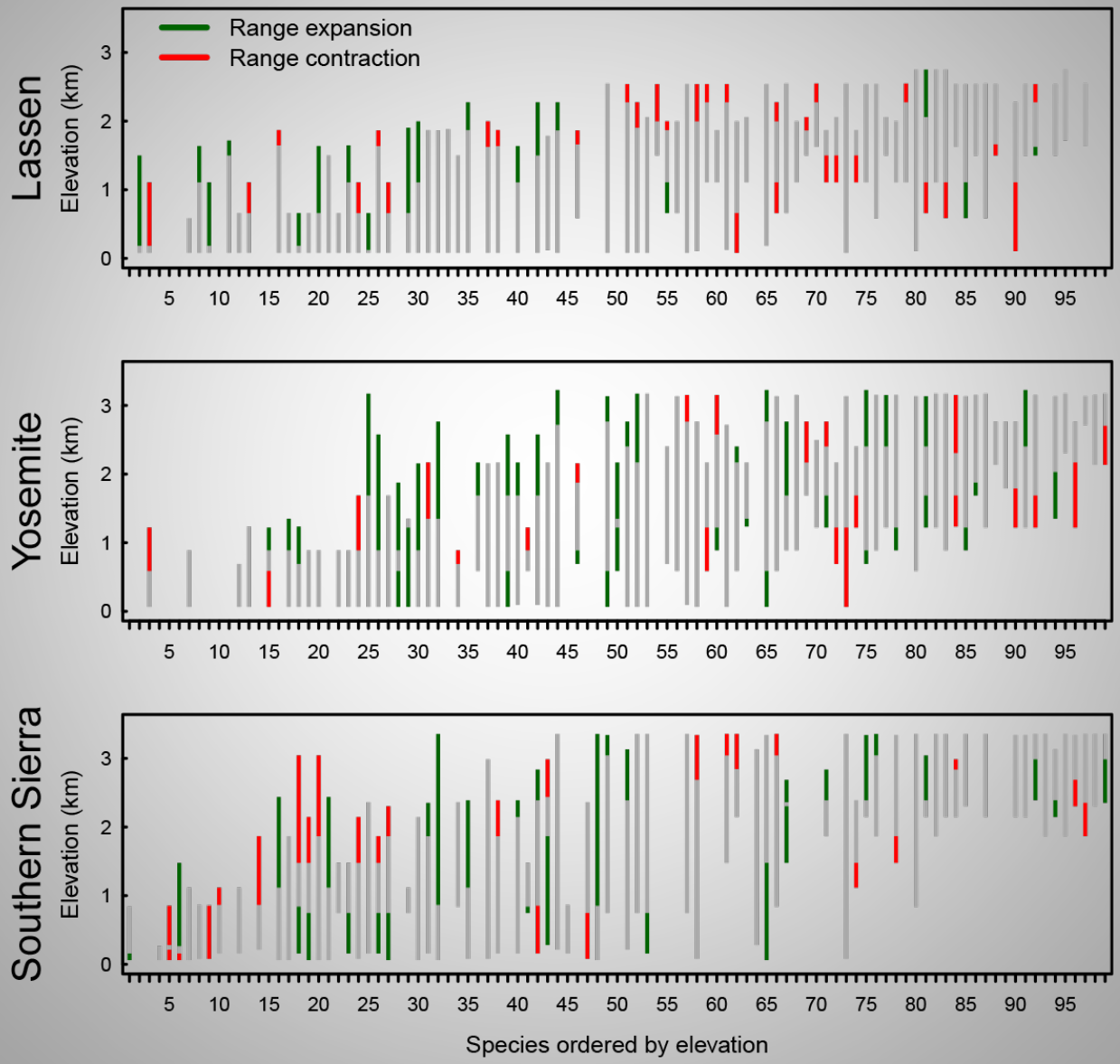


Western gray squirrel
(*Sciurus griseus*)



*Rowe et al. 2015 Proc Royal Soc B 282: 20141857*

# Avian Elevational Range Response

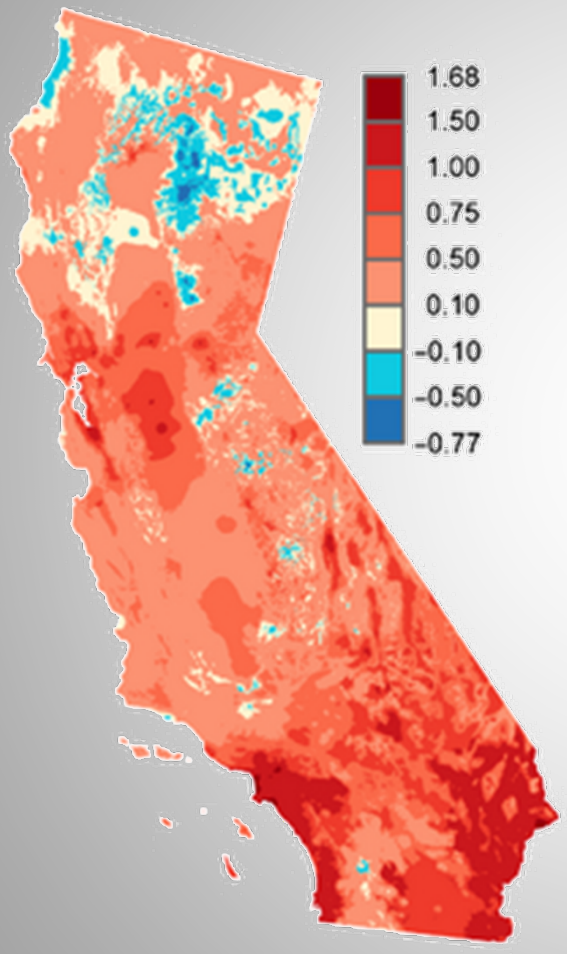



*Tingley et al. 2012 Glob Change Biol 18: 3279-3290*

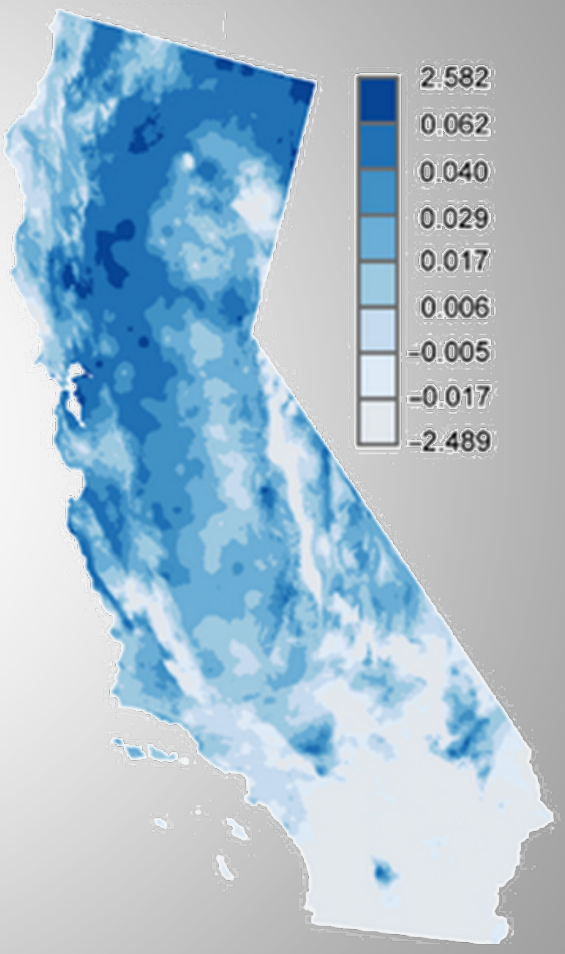
# Effects of Climate Change on Terrestrial Vertebrate Ranges

- Elevational Range Dynamics
  - Are naïve predictions of upward shifts sufficient?
  - Dynamics at a broader spatial extent
  - The shortcomings of the naïve approach

# Climate Change Since Grinnell: Substantial and Highly Variable




Δ mean temp. (°C)

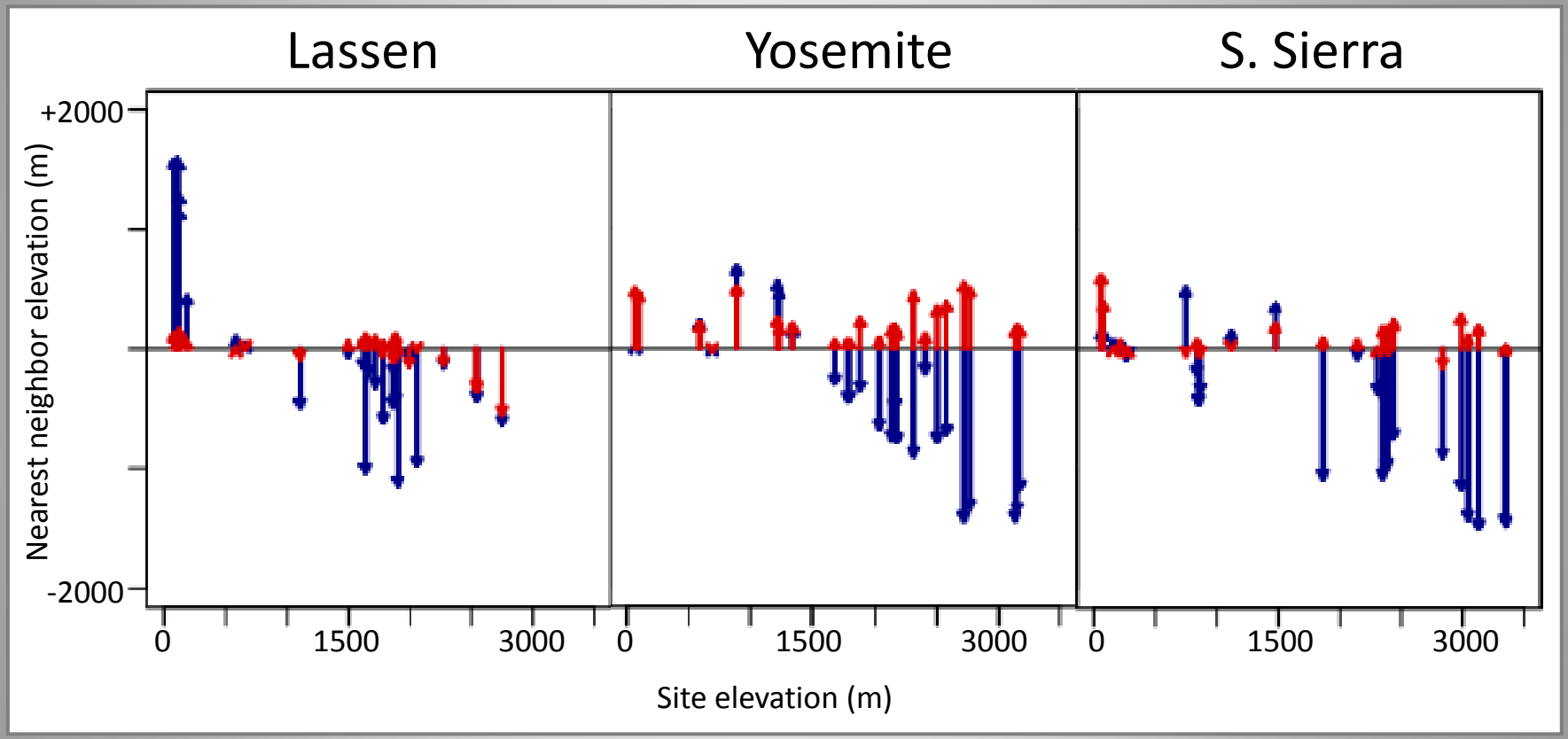



Δ total precip (mm)

*Rapacciuolo et al. 2014 Glob Change Bio 20:2841-2855*

# The Elevational Push and Pull of Climate Change:

## Nearest Climatic Neighbor (Temperature and Precipitation)

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- Elevational Range Dynamics
  - Are naïve predictions of upward shifts sufficient?
  - Dynamics at a broader spatial extent
  - The shortcomings of the naïve approach
- Predictors of Range Change

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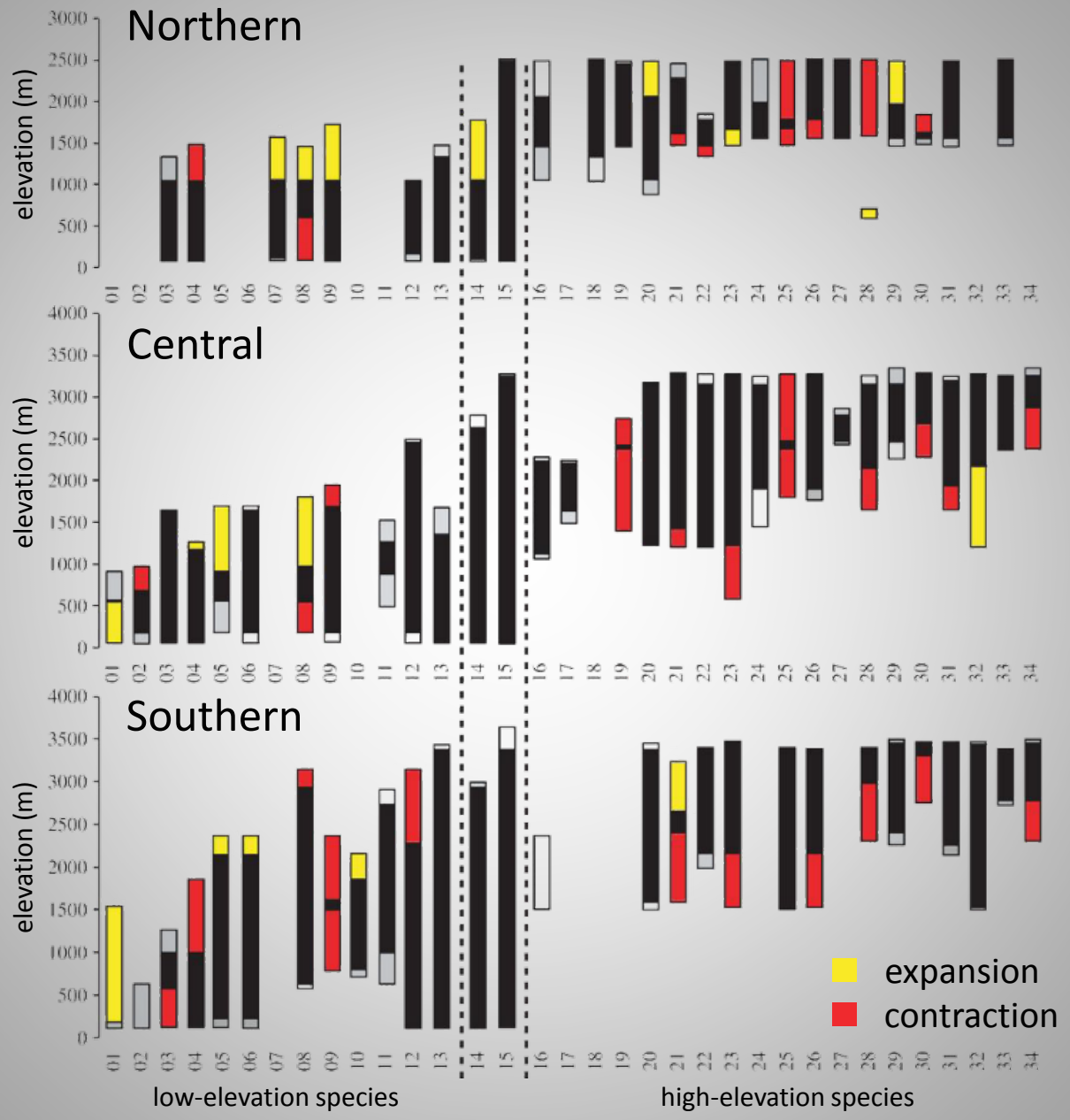
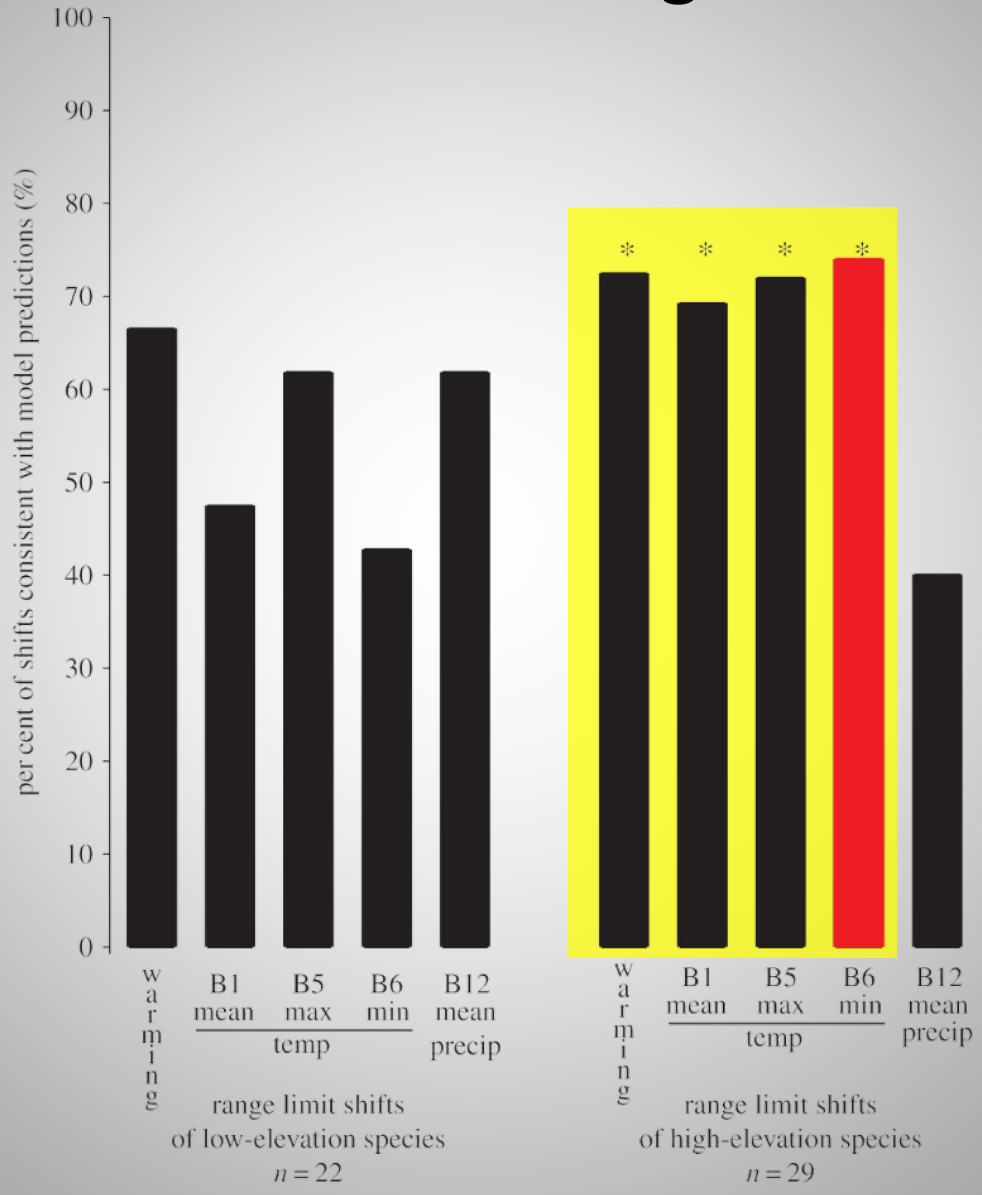
- Elevational Range Dynamics
  - Are naïve predictions of upward shifts sufficient?
  - Dynamics at a broader spatial extent
  - The shortcomings of the naïve approach
- Predictors of Range Change
  - Climate




Rowe et al. 2015 Proc Royal Soc B 282: 20141857

# Climate Change Predictions: Small Mammal Range Shifts

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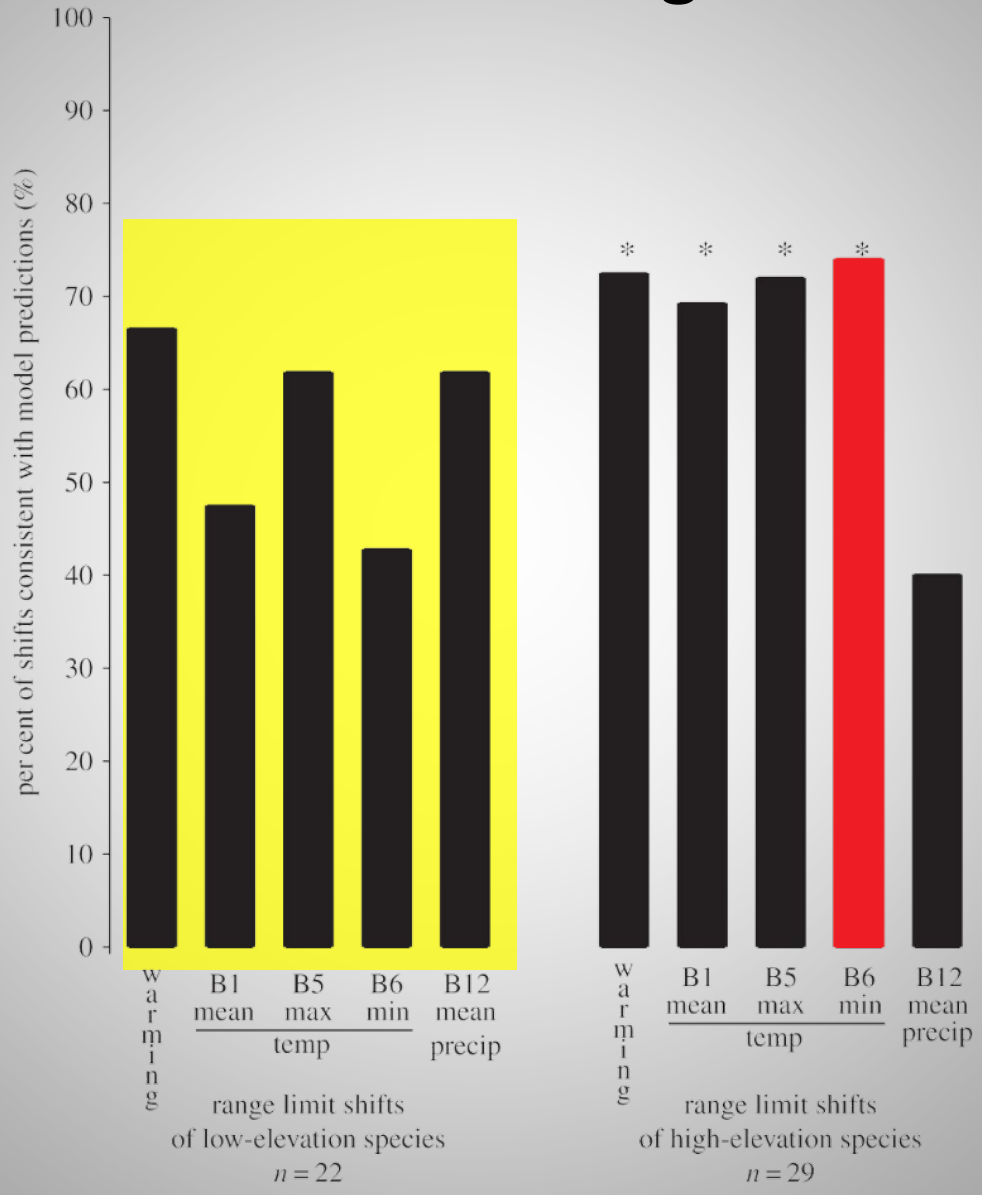


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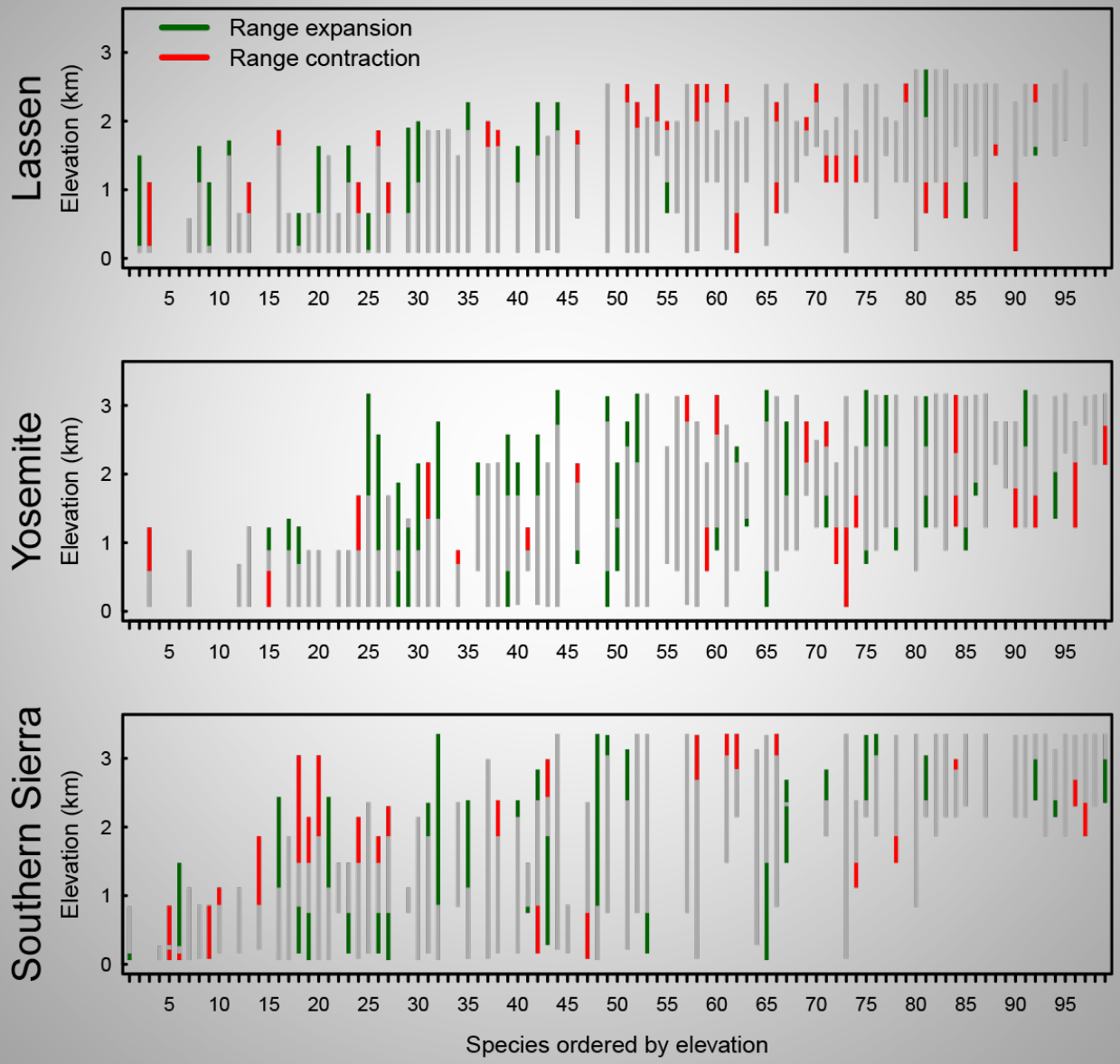
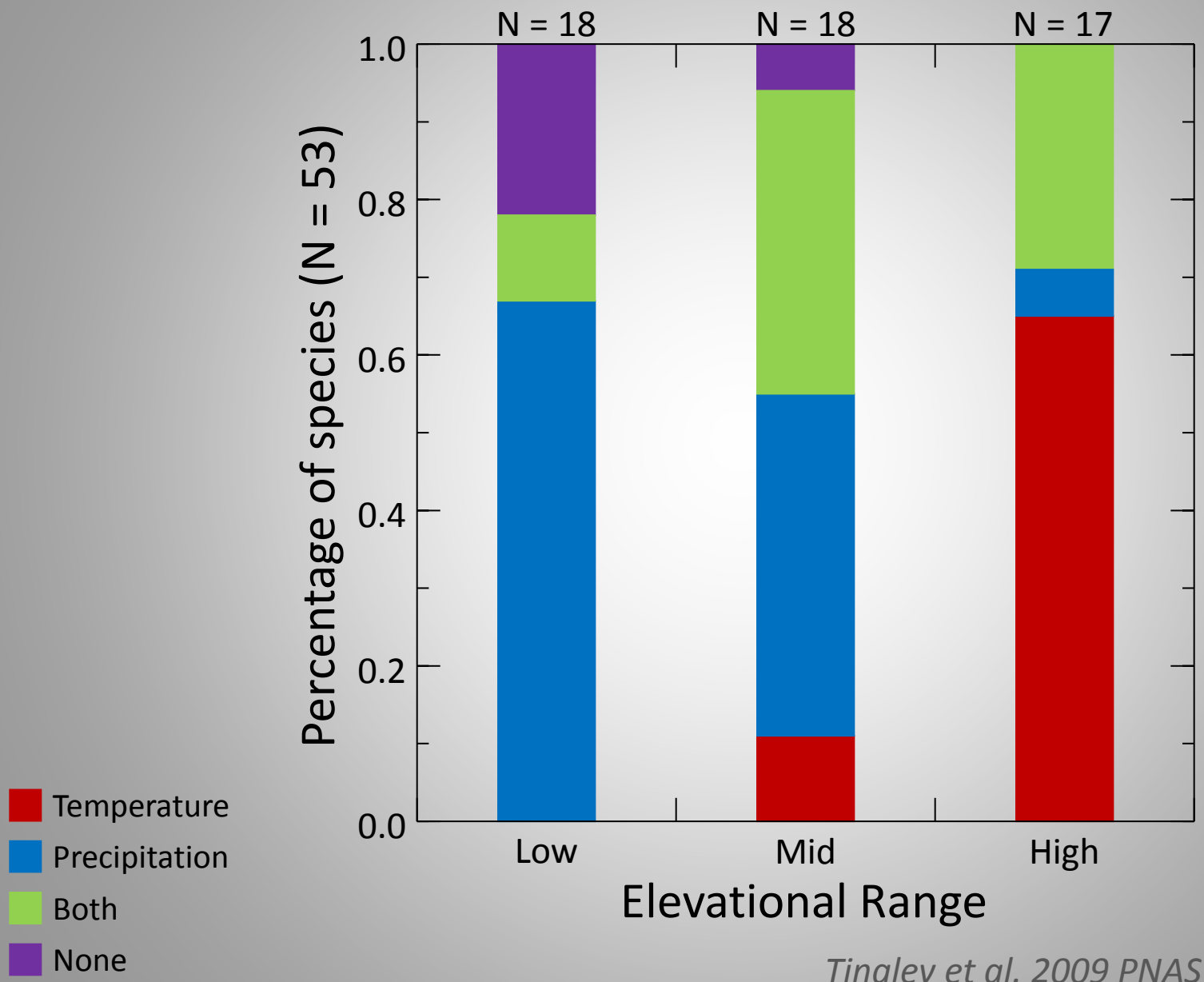
# Climate Change Predictions: Avian Range Shifts




*Tingley et al. 2012 Glob Change Biol 18: 3279-3290*

# Elevational Differences in Avian Niche Tracking




*Tingley et al. 2009 PNAS 106: 19637-19643*

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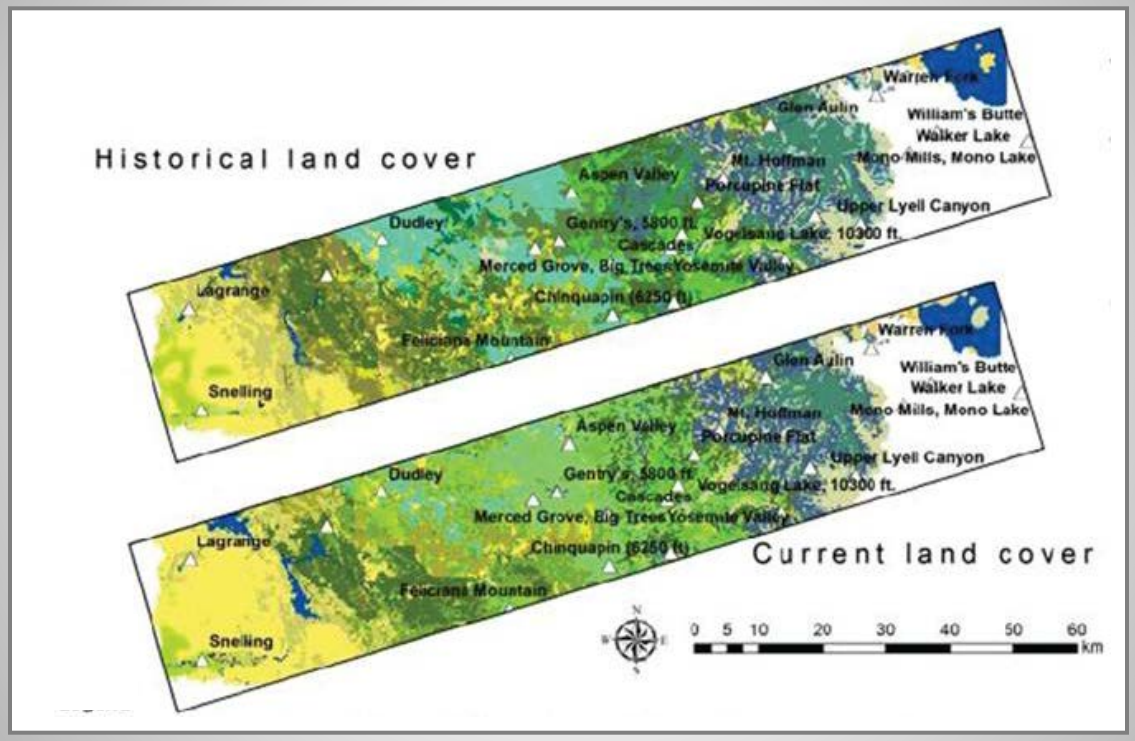
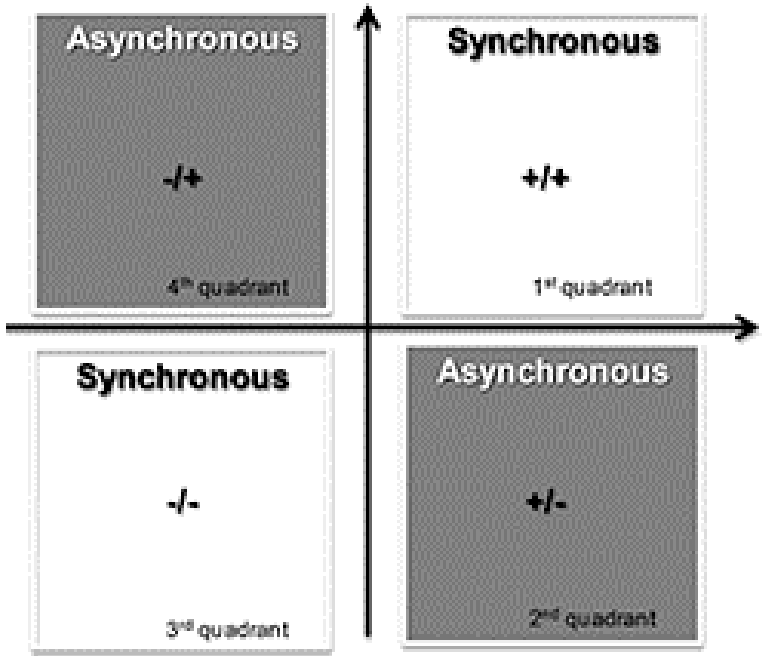
  - The shortcomings of the naïve approach
- Predictors of Range Change
  - Climate
  - Vegetation

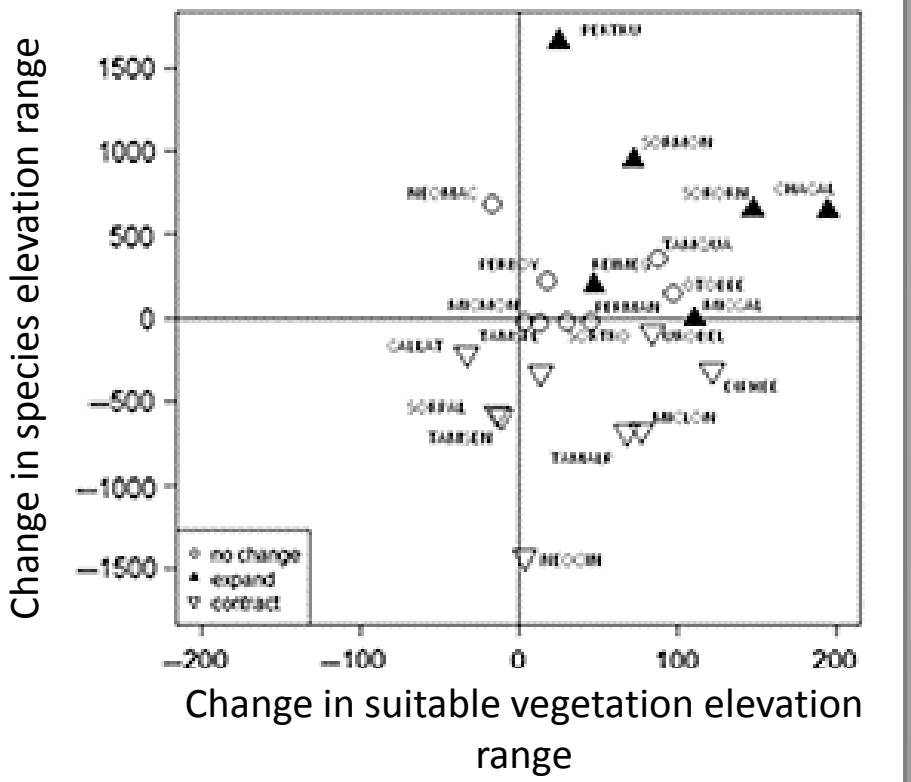
# Vegetation Change: Yosemite Transect Mammals




*Santos et al. 2015 Ecography 38, 556–568*

# Vegetation Change: Synchronicity in Mammalian Shifts

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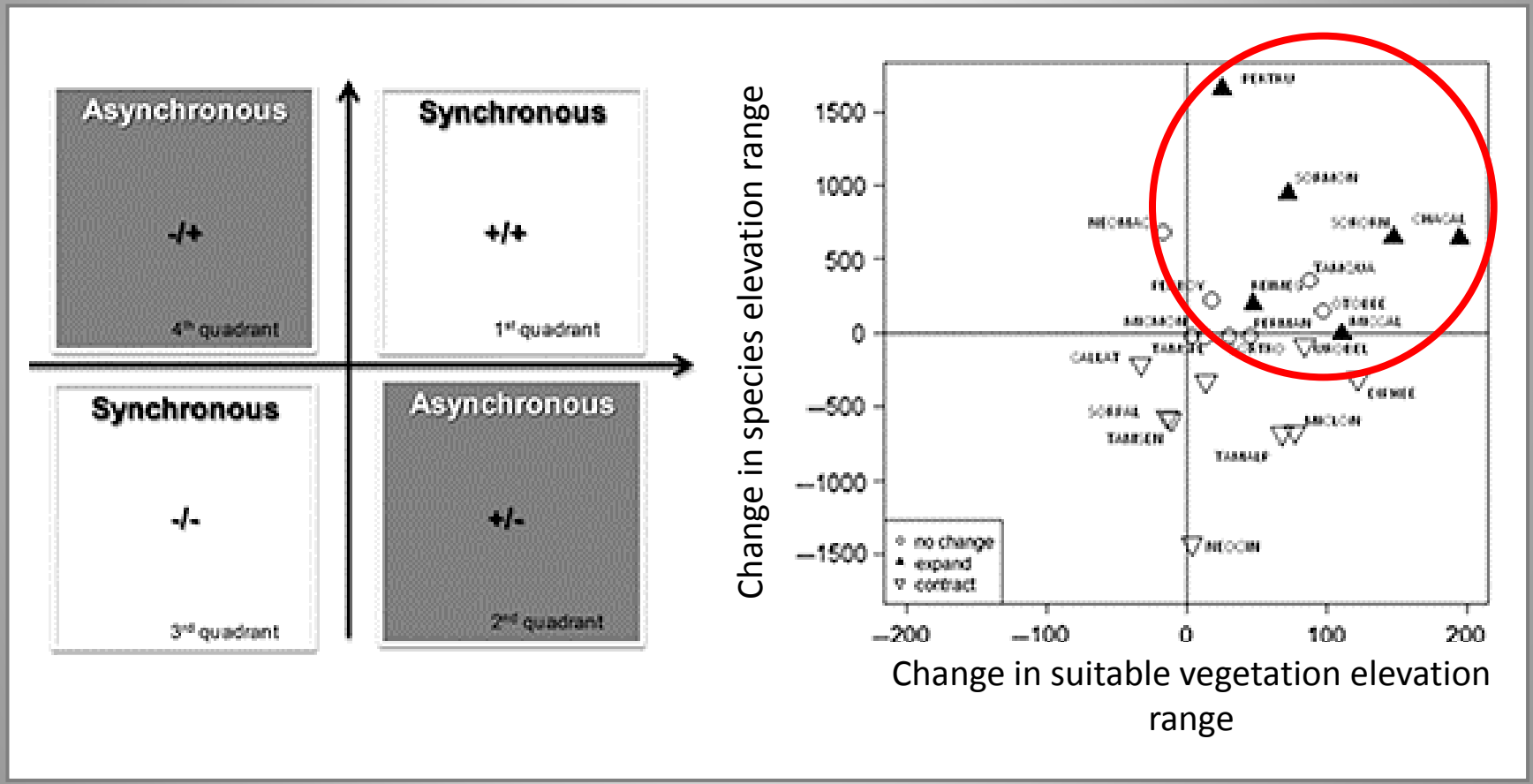


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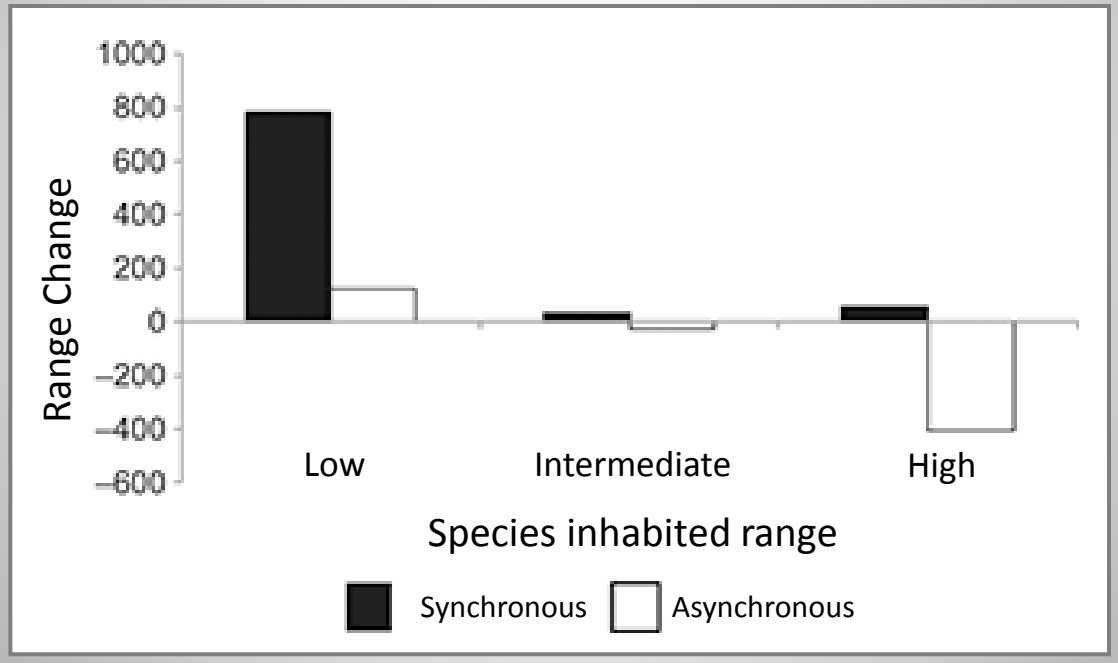


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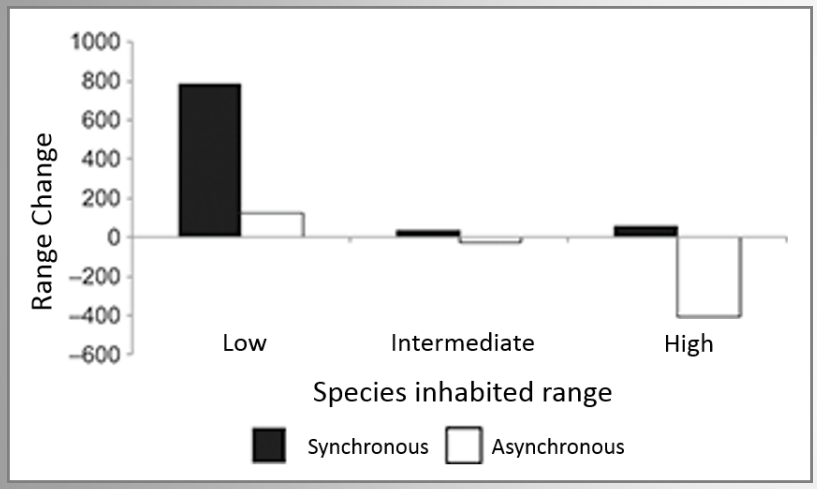
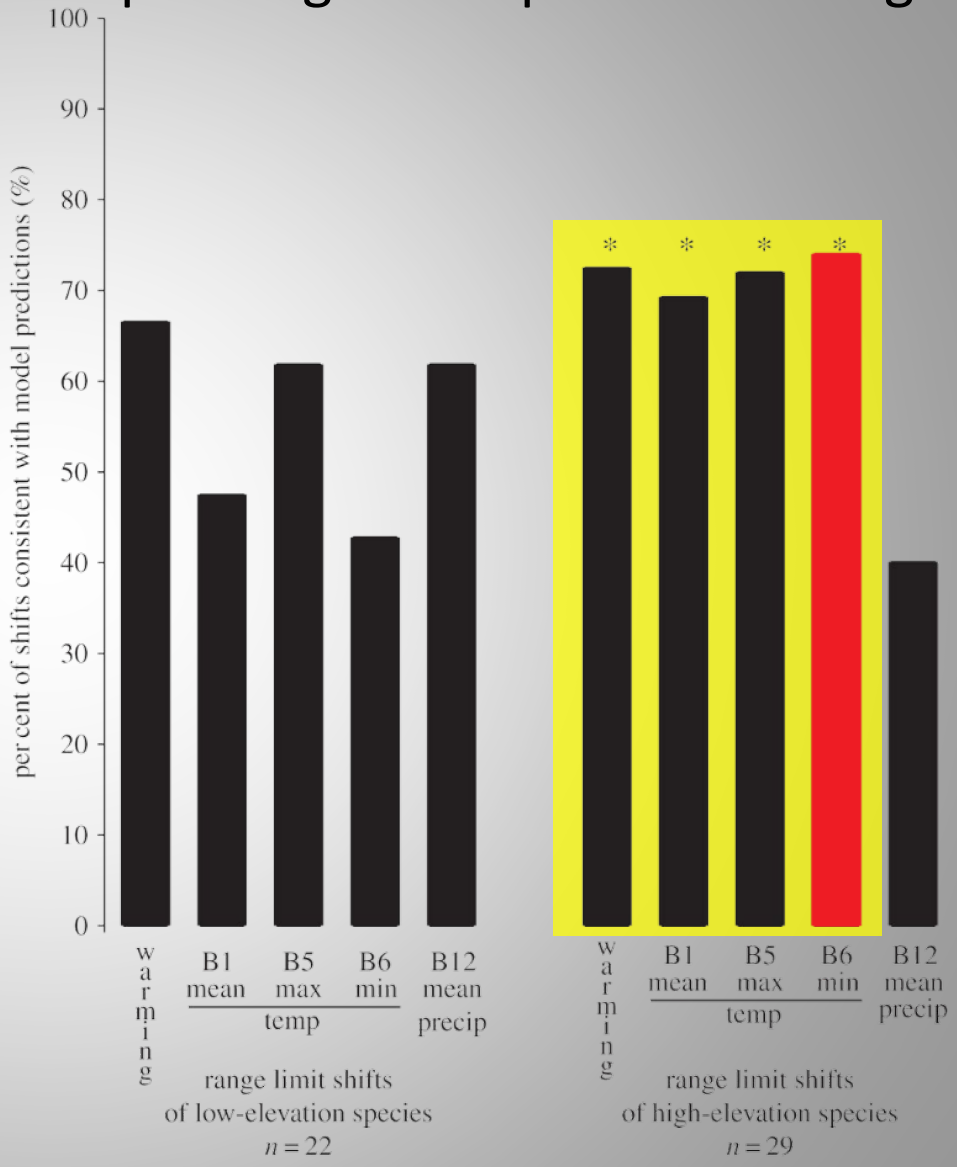
## Low-elevation: responding to vegetation change




## High-elevation: responding to temperature change




*Rowe et al. 2015 Proc Royal Soc B; Santos et al. 2015 Ecography*

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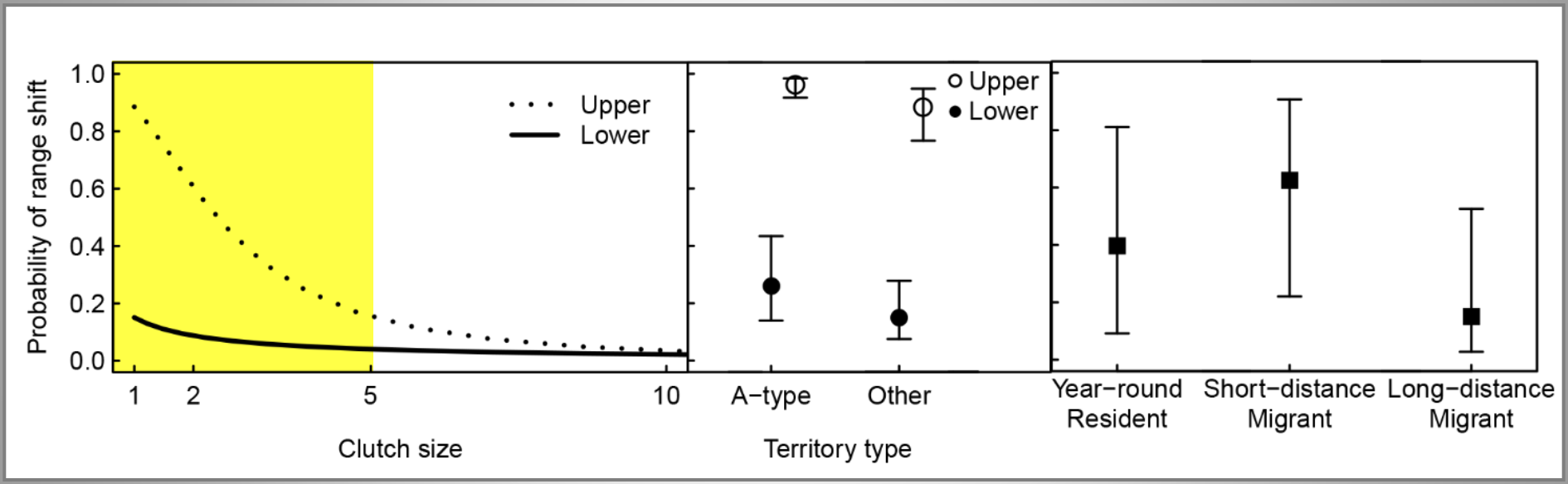
  - Dynamics at a broader spatial extent
  - The shortcomings of the naïve approach
- Predictors of Range Change
  - Climate
  - Vegetation
  - Life-history traits

# Life History Traits: Birds




*Tingley et al. 2012 Glob Change Biol 18: 3279-3290*

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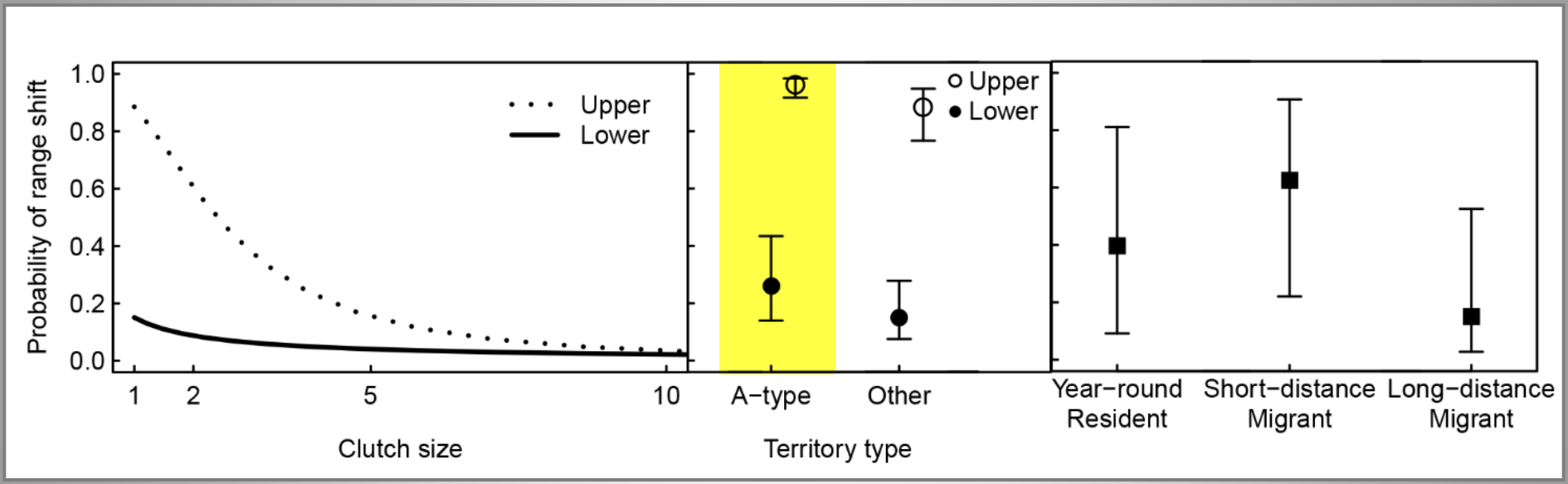


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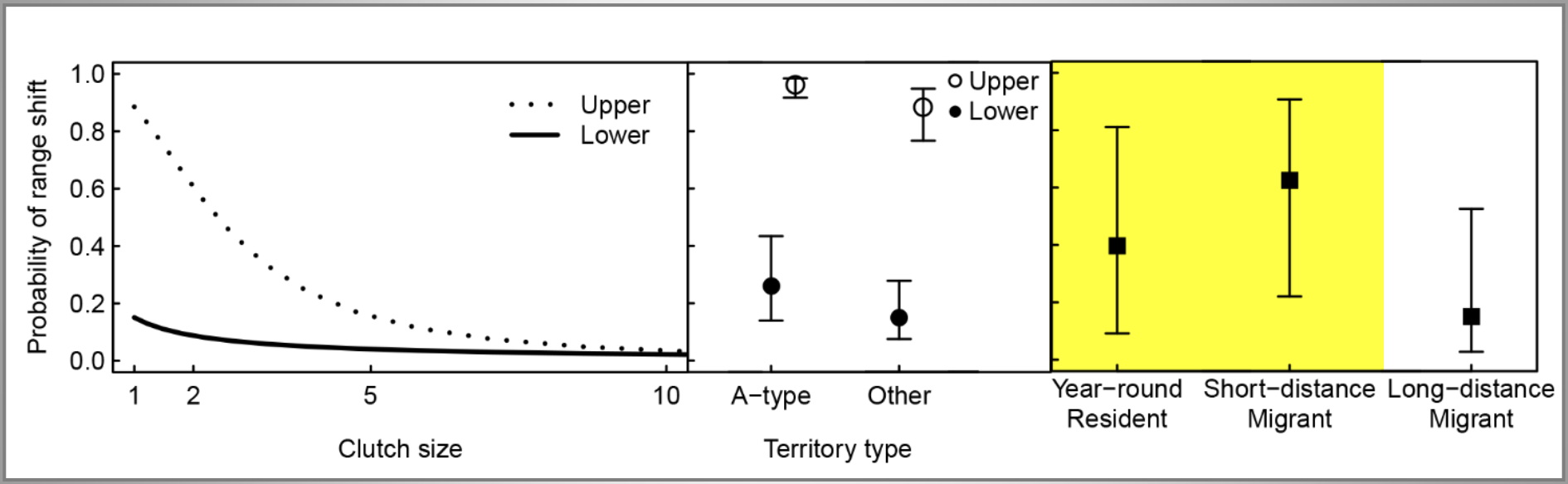
# Life History Traits: Birds

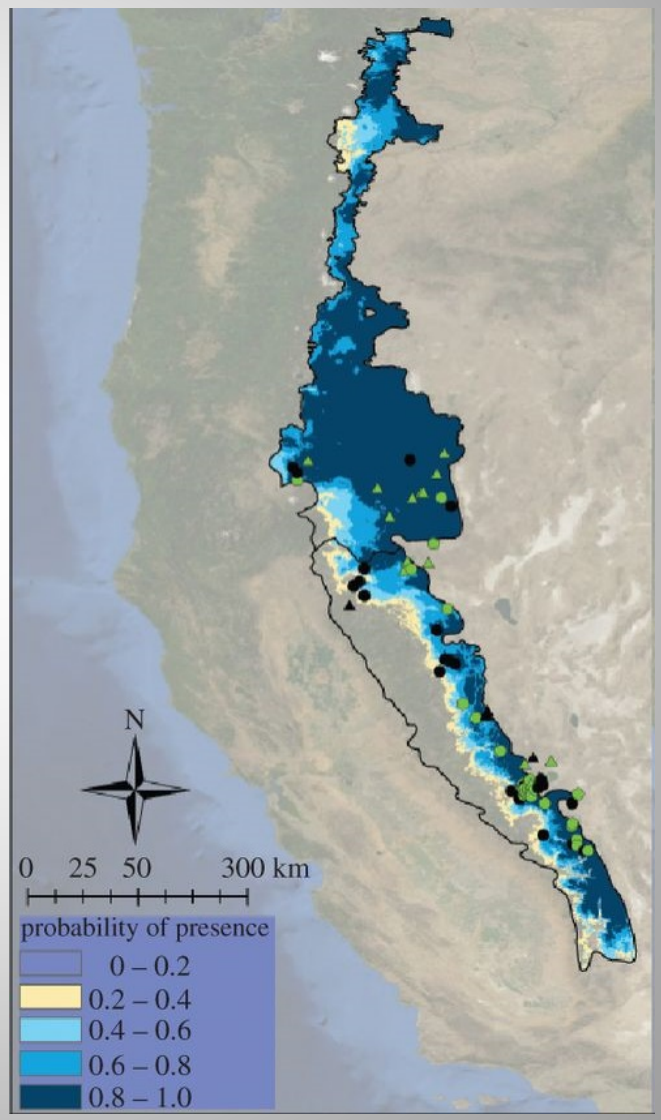



*Tingley et al. 2012 Glob Change Biol 18: 3279-3290*

# Effects of Climate Change on Terrestrial Vertebrate Ranges

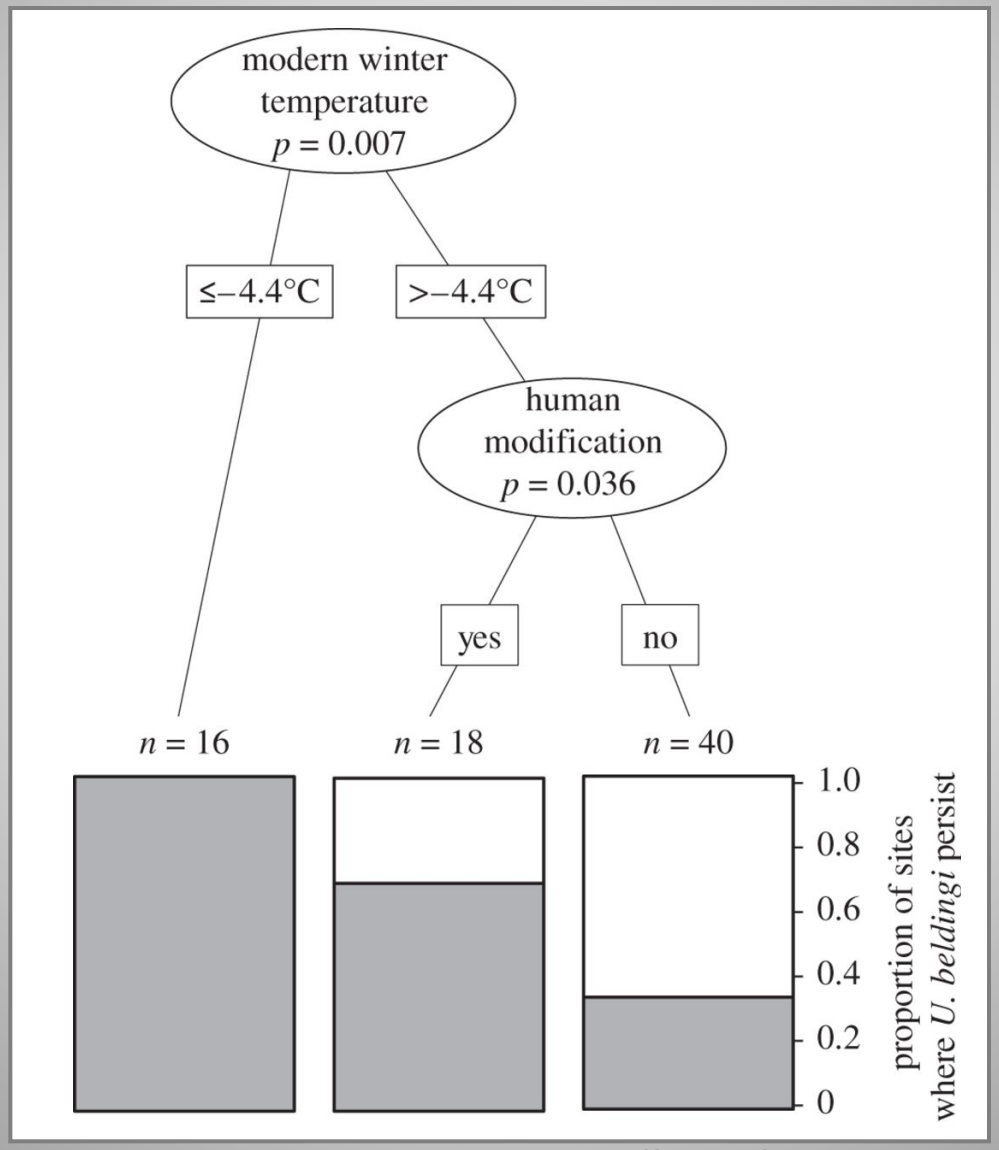
- Elevational Range Dynamics
  - Are naïve predictions of upward shifts sufficient?
  - Dynamics at a broader spatial extent
  - The shortcomings of the naïve approach
- Predictors of Range Change
  - Climate
  - Vegetation
  - Life-history traits
  - Anthropogenic Climate Refugia

# Anthropogenic Climate Refugia:
## Belding's Ground Squirrel




*Morelli et al. 2012 Proc R Soc B 279, 4279–4286*

# Anthropogenic Climate Refugia: Belding's Ground Squirrel




*Morelli et al. 2012 Proc R Soc B 279, 4279–4286*

# Summary: Elevational Range Dynamics

- Naïve predictions of upward shifts
- The shortcomings of the naïve approach
  - Substantial heterogeneity in temperature/precipitation change
  - Large amounts of heterogeneity in regional species' range responses

# Summary: Predictors of Range Change

- Climate
  - Mammals:
    - High-elevation species: consistent with temperature
    - Low-elevation species: unpredictable by temperature or precipitation
  - Birds:
    - High-elevation species: tracked temperature
    - Low-elevation species: tracked precipitation
    - Intermediate-elevation: tracked both
- Vegetation
  - Mammals:
    - Low-elevation species expansions: synchronous with vegetation expansions

# Summary: Predictors of Range Change

- Life-history traits
  - Mammals:
    - Weak support
  - Birds, more likely to shift if:
    - small clutch sizes
    - all-purpose territories
    - year-round residents
- Anthropogenic Climate Refugia
  - Mammals:
    - support low-elevation persistence (n=1)